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Waste Research Strategy

External Review Draft

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Executive Summary

Chapter 1: Introduction and Background

This document presents a strategy to guide hazardous waste research within EPA's Office of Research and Development (ORD). As such, it first summarizes the major waste-related environmental problems facing the United States, then proposes a process for selecting the most important areas for research, and describes priority research activities. This strategy identifies five (5) research topic areas which correspond to the major waste-related environmental problems (e.g., contaminated ground water, contaminated soil/vadose zone, emissions from waste combustion facilities, active waste management facilities, and technical support) for which research plans are subsequently developed in the appendices of the document.

Purpose

The purpose of this strategy is to apply ORD's general strategic principles, goals and ranking criteria to set priorities for waste-related research. These priorities will be used by ORD research laboratories to focus their efforts on the most important areas of research through fiscal year 2000. Stakeholders outside of ORD can use the strategy to identify research needs and priorities.

Structure of the Plan

This report is organized in three chapters. Chapter 1 summarizes the major waste problems facing the United States, associated risks to human health and the environment, and costs of proper management and cleanup. Chapter 2 contains the essence of the strategy. It first lists waste research needs; then describes the five environmental problem areas ("research topics") ORD selected to address, along with related research activities for each topic; and finally presents the ranking of the activities with the rationales for the rankings. The conclusions of the strategy are discussed in Chapter 3 along with outstanding issues that require further evaluation.

Nature and Scope of the Problem

This strategy covers research necessary to support both the proper management of solid and hazardous wastes, and the effective remediation of abandoned waste sites. As such, it responds to two major legislative mandates and large programs within the USEPA -- The Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or "Superfund") and their amendments.

The number of *existing* RCRA waste management facilities and *abandoned* Superfund waste sites is very large and their potential risks to human health may be significant because of numerous releases of contaminants to the environment.

Abandoned waste sites have been reported to present a risk to human health. The recent Agency for Toxic Substances and Disease Registry (ATSDR) report to Congress found that some heavy metals, volatile organic compounds, and other specific substances occur at levels of health concern in the bodies of exposed people. ATSDR concluded that "uncontrolled hazardous waste sites and unplanned releases of hazardous substances that constitute emergency events are a major environmental threat to human health." (ATSDR, 1966)

Waste management and remediation also have major impacts on the economy. The average cost of a Superfund site remediation was about $27M per site in 1993, and at some sites the costs have been several hundred million dollars. One recent, report concluded that over the next 30 years, the nation as a whole will spend $480 billion to $1 trillion, with a "best guess" of $750 billion, cleaning up sites. (Russell et al., 1991, NRC, 1994).

Chapter 2: Setting Research Priorities

Research priorities for waste-related research were set by using the general strategic principles, methods and criteria identified in the *ORD Strategic Plan* and then adapting them for application to waste research topics and activities. Specifically, this entailed developing a ranking scheme comprised of the following steps: (1) identify research needs, (2) filter (preliminary) research needs, (3) identify research topic areas and activities, (4) rank research activities, (5) filter (final) research activities, and (6) select research activities.

Identification of Research Needs

Research needs were identified from two major sources: those identified by the CENR that were relevant to the EPA's mission, and those identified by the various programs within the Office of Solid Waste and Emergency Response and the Regional Waste offices. The latter needs were sorted and categorized as either higher, medium, or lower priority needs. Over one hundred needs were identified during this exercise.

Preliminary Filter of Research Needs

A preliminary filtering of these research needs was conducted to identify Congressionally mandated research programs and to identify other research programs established by Congress to conduct certain types of Superfund related research. Results of applying these filters identified two research programs that are mandated by legislation for explicit ORD attention--the Superfund Innovative Technology Evaluation (SITE) program and the Hazardous Substance Research Centers (HSRCs).

In addition, two other research programs were filtered out of the ORD list of research activities: (1) epidemiological studies of waste sites to evaluate whether exposure has occurred was dropped because it is the legislative mandate for the Agency for Toxic Substances and Disease Registry (ATSDR), and (2) nuclear wastes and/or other

defense-related or energy-related wastes because ORD views these issues as largely the responsibility of the Department of Defense (DOD) and the Department of Energy (DOE).

Identification of Research Topic Areas and Associated Research Activities

Five broad research topics areas were established which represent the major waste-related research problems (note that although technical support is not an environmental problem, it was identified as a major topic area):

(1) Contaminated Sites -Ground Water
(2) Contaminated Sites -Soils / Vadose Zone
(3) Emissions from Waste Combustion Facilities
(4) Active Waste Management Facilities
(5) Technical Support

Next, 39 research activities were identified that would address the major research needs within the first four topic areas.

Prioritization of Research Activities

Using the three sets of ranking criteria identified in the ORD Strategic Plan, ordinal rankings were developed for the research activities within each research topic area. Research activity rankings were first developed based on science criteria only. Uncertainty in risk assessment, efficacy and cost-effectiveness of risk management technologies, and the broad applicability of methods and models were the primary criteria in establishing the science ranking. The final rankings (shown in parentheses next to each research activity in Table ES-1) also considered a number of other non-science factors (this final ranking is referred to as the "Science Plus" ranking). Examples of these other factors include such items as: an Administration priority; a CENR research priority; a Program Office priority; regulatory or legal mandates; priorities in Agency; Congressional directives; and FY98 area for new funding.

Final Filter of Research Activities

In addition to earlier filtering out research it considers more appropriate to other federal organizations, the Research Plan also filtered out research that: (1) it considers more appropriate for or is being conducted by other research programs within ORD; or (2) does not fall within the mission, goals and/or expertise of a particular ORD Laboratory or Center. Research activities that were filtered out of the Waste Research Program in this final process were: (1) Ecosystems Effects, and (2) Chemical Toxicity Testing for Human and Ecological Endpoints.

Selected Waste Research Activities

Table ES-1 presents the remaining research activities addressed by the Waste Research Strategy. The final Science Plus rankings of the research activities are shown in parenthesis. In addition, there are four additional research activities associated with the Technical Support research topic. These are technical support for risk assessment, exposure assessment, remediation, and monitoring.

Preliminary research plans are presented for the five research topic areas in Appendices D through H of the report. These appendices describe the work which ORD would propose to do in each research activity through FY00 if there are adequate resources.

Chapter 3: Conclusions and Issues

Conclusions

There is a large and diverse set of waste research needs that span the spectrum of the risk paradigm. As a result, well integrated research programs are needed for each research topic area which have the goal of improving our assessment, characterization and risk management capabilities. Also, because there are insufficient resources available to meet all these research needs, the process of ranking research topics and activities is critical.

Five broad research topic areas were identified to cover the full range of waste-related research. These are: (1) contaminated ground water, (2) contaminated soils/vadose zone, (3) active waste management facilities, (4) emissions from waste combustion facilities, and (5) technical support. The highest priority research activities in each are:

- Contaminated ground water: The focus of the research activities is on the issues of: improved risk assessment, characterization and remediation of non-aqueous phase liquids (NAPLs), the application and management of natural and accelerated process for subsurface remediation, and the demonstration and verification of innovative characterization and remediation technologies.
- Contaminated soil/vadose zone: The focus of research activities is on the issues of improved exposure and risk assessment of soils, the application and management of natural and accelerated process for remediation, and the demonstration and verification of innovative characterization and remediation technologies in soils and the vadose zone.
- Active waste management facilities: The focus of the research activities proposed for this research topic area is on the science needs related to the Hazardous Waste Identification Rule (HWIR) especially in multimedia, multipathway modeling and the development or estimation of toxicity values.
- Emission from waste combustion facilities: The focus of research in this topic areas is on the control and monitoring of emissions, emissions fate process and

transport modeling, and indirect exposure and risk assessment methods and models.

- Technical support: Site-specific technical support is provided in the areas of exposure modeling, risk assessment, measurement and monitoring, and remediation. In addition, technology transfer activities and technical support to the Program Office are described.

While there is much uncertainty, debate, and controversy about the health and ecological risks posed by waste sites, there is consensus that the economic impact of current waste management and cleanup practices is staggering. Within this context, waste research should be viewed as a relatively small but valuable investment to save future expenditures.

Because of the multi-disciplined nature of waste-related research, there are many organizations (across government, industry, and academia) actively involved in sponsoring research activities. In order to maximize efficiency of effort and avoid duplication, special efforts need to be made to coordinate and leverage these research programs and activities.

ORD's current research program emphasizes risk management research. There is a need to increase the relative amount of risk assessment research in this program.

Issues

Several issues were identified that may require further attention.

- The lack of risk characterization research.
- Future waste strategy development.
- Funding Strategies.

Table ES-1. Selected ORD Waste Research Program Research Activities

Research Topic Areas (In Priority Order)	RESEARCH ACTIVITIES BY RISK PARADIGM CATEGORIES					
	Risk Assessment			*Risk Management*		
	Exposure Assessment	Toxicity Assessment	Risk Characterization	Remediation & Restoration	Control	Monitoring
Contaminated Sites - Ground Water	- Environmental Fate and Transport Modeling (7)* - GW Exposure Factors / Pathways (21)	- Mixtures Toxicology (26) - Ecological Risk Assessment Methods (38) - Human Dose-Response Models for Mixtures (3)		- Natural Attenuation (2) - Abiotic Treatment of GW (9) - Biotreatment of GW (16) - Containment of GW (17) - Demonstration/ Verification of Innovative Remediation Technologies (27)		- Subsurface Characterization (6) - Field and Screening Analytical Methods for GW (5) - Demonstration/ Verification of Field Monitoring Technologies (27)
Contaminated Sites - Soils / Vadose Zone	- Estimating Human Exposure & Delivered Dose (1) - Estimating Soil Intake and Dose -Wildlife Species (3)	- Ecological Screening Tests to Measure the Effectiveness of Treatment (18) - Mixtures Toxicology (34)		- Biotreatment of Soils (3) - Containment of Soils (18) - Demonstration/ Verification of Innovative Remediation Technologies (27) - Abiotic Treatment of Soils (31) - Oil Spills (36)		- Field Sampling Methods (8) - Field and Screening Analytical Methods for Soils (9) - Sampling Design (22) - Demonstration/ Verification of Field Monitoring Technologies (27)
Emissions from Waste Combustion Facilities	- Indirect Exposure Characterization/ Modeling (13) - Indirect Pathway Risk Assessment Methods (11)	- Movement of Bioaccumulative Chemicals in Food Webs (33) - Dose-Response of Key Contaminants (24)			- Emissions Prevention and Control (12)	- Continuous Emissions Monitoring (CEMs) Methods (23)
Active Waste Management Facilities	- Multimedia, Multipathway Exposure Modeling (14) - Environmental Fate and Transport; Physical Estimation (25)	- Developing Provisional Toxicity Values for Contaminants (18)			- Waste Management (36)	- Waste Characterization and Sampling (32)

* Equals the ordinal rank of each research activity across the entire Waste Research Program based on the science plus ranking factors.

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Chapter 1
Introduction and Background

Research Strategy Purpose, Scope, and Structure

This document presents a research strategy to guide solid and hazardous waste research in the EPA Office of Research and Development (ORD). The strategy summarizes the major waste-related environmental problems facing the United States; identifies the five most important ones for the ORD to pursue through fiscal year 2000 (FY00); and describes a process for determining where ORD should utilize its limited funding resources, but significant technical expertise, on these problems. The strategy then identifies and prioritizes the research activities that need to be conducted for each of these five problem (or "research topic") areas. Appended to this strategy are five preliminary research plans, one for each research topic area.

Purpose

The purpose of the research strategy described in this document is to apply ORD's strategic principles, goals and ranking criteria, as presented in *the 1997 Update to ORD's Strategic Plan* (ORD, 1997a), to ORD's waste research program. The waste strategy documents the research directions that ORD plans to pursue in addressing waste-related environmental problems through FY00, and provides guidance for making decisions annually on how to pursue these goals. The strategy provides guidance to EPA Laboratories and Centers for developing more narrowly focused laboratory plans needed to conduct each of the research activities described herein. This strategy is also intended to inform other stakeholders about EPA waste research plans.

The five appended preliminary research plans serve several purposes. First, they provide details needed to understand strategic priorities. Second, they provide general guidance to ORD Laboratory and Center researchers on where to focus their efforts for research activities that do receive funding through FY00. Third, they provide other stakeholders with a sense of how that strategy is being proposed for implementation.

Scope

This strategy addresses waste-related environmental problems that are of greatest importance from both the perspective of ORD's research ranking criteria and the perspectives of the EPA Office of Solid Waste and Emergency Response (OSWER) and the EPA Regions. The research activities described herein are those associated with the assessment and remediation of contaminated sites (e.g., Superfund and RCRA sites), as well as the risks associated with waste management (i.e., treatment, storage and disposal). Research on the assessment and remediation of oil spills and of sites contaminated by leaking underground storage tanks (USTs) is also discussed in this

document because of the many similar technical issues. A fourth important waste management research area, pollution prevention, is addressed in a separate ORD Research Plan (ORD, 1997b) and is not discussed here. Also, contaminated sediments are not explicitly addressed in this document because there is separate research planning activity for this topic (ORD, 1997c). (ORD research planning activities for both pollution prevention and contaminated sediments are summarized in Appendix C).

Structure

This plan is divided into three chapters. Chapter I describes major waste problems faced by the United States, and their associated risks and risk management costs. This chapter also describes the mission and goals of the ORD Waste Research Program and describes the relationship of this research plan to the ORD Strategic Plan. Chapter 2 describes waste research needs identified by ORD, EPA's Program Offices, EPA Regions, and others. Five research topic areas are identified along with a set of research activities that need to be carried out for each topic area. These research activities are then prioritized based upon a waste ranking scheme that utilizes ORD's strategic planning principles. Chapter 3 provides conclusions from the strategic planning process and summarizes planning issues that remain to be addressed.

This document includes eight appendices. ORD waste "issue plans" that up until recently were used for ORD research planning are summarized in Appendix A. A summary of waste-related environmental research needs is provided in Appendix B as a series of six tables, each describing research needs within one of the six Committee on the Environment and Natural Resources (CENR) risk paradigm categories (discussed in detail later in this chapter). Appendix C provides a summary of other waste-related research programs in ORD, OSWER, other federal agencies, and the private sector.

The last five appendices (Appendices D-H) are preliminary research plans for the five topic areas that this research strategy recommends. They are:

- Contaminated Sites - Ground Water
- Contaminated Sites - Soil/Vadose Zone
- Active Waste Management Facilities
- Emissions from Waste Combustion Facilities
- Technical Support

Each appendix describes the research activities that ORD would need to carry out (subject the breadth of its available expertise) to fully address the environmental problems in Chapter 2. These may be carried out by staff in an ORD research Laboratory or Center, or as part of ORD's research grants program. These appendices

explains why each research activity is important, what its objectives are and what research would be conducted in this four-year period. Anticipated major research products (including products of EPA grants) are listed for each activity with current estimates for their completions. These dates are estimates for fiscal planning purposes only. A summary table is also provided at the end of each research plan. It summarizes the major products that ORD proposes to produce, subject to adequate resources.

These research plans are preliminary and should be considered under development. They are structured parallel to the research topic areas identified in Chapter 2. Within a research topic area, research activities are subcategorized by the six components of the CENR risk paradigm. A table of contents is provided at the beginning of each appendix for ease in locating specific research activities.

Nature and Scope of the Problem

Hazardous and Solid Waste Management

In 1965, Congress passed the Solid Waste Disposal Act, the first law to require safeguards and encourage environmentally sound methods for disposal of household, municipal, commercial, and industrial refuse. Congress amended this law in 1970 by passing the Resource Recovery Act and again in 1976 by passing the Resource Conservation and Recovery Act (RCRA). Congress revised RCRA first in 1980 and again in 1984. The 1984 amendments (referred to as the Hazardous and Solid Waste Amendments [HSWA]) significantly expanded the scope of RCRA. The major sections of the statute are:

- Subtitle C, which establishes a program for managing hazardous waste from generation to ultimate disposal.
- Subtitle D, which establishes a program for managing solid (primarily nonhazardous) waste, such as household waste.
- Subtitle I, which regulates toxic substances and petroleum products stored in underground tanks.

Hazardous Waste Facilities

A total of 400,000 facilities have reported generating RCRA hazardous waste in the U.S. (OSW, 1993a). About 200 million tons of hazardous waste are generated each year by the largest generators (OSW, 1993b). While far fewer are active today, historically more than 5,000 facilities have been involved in the treatment, storage and disposal of hazardous waste. These facilities, with approximately 100,000 solid waste management units, are potentially subject to RCRA's cleanup program. One study estimates that 2,200 of these facilities will have releases to the environment which are likely to require corrective action. The study indicates that cleanup is driven by ground

water and soil contamination, and cancer or non-cancer risks of concern are estimated to occur at between 1,900 and 2,200 hazardous waste management facilities. Roughly 500 of these sites are estimated to have onsite ground water plumes which are over 10 acres in area. Roughly 1,700 facilities are projected to have contaminant releases to onsite soil that exceed safe levels. Of the facilities needing cleanup, 350 are estimated to have over 1 million cubic feet of contaminated soil. EPA currently is addressing roughly 1,500 facilities under the RCRA corrective action program (OSW, 1993c).

Some waste streams not managed under RCRA Subtitle C include constituents that require safe management to protect human health and the environment. Certain large-volume categories of primarily non-hazardous waste include constituents, such as hazardous metals, that may pose serious risks to exposed populations and cause extensive environmental damage. Large-volume wastes include oil and gas industry waste, mining wastes, waste created from fossil fuel combustion, and cement kiln dust. Overall, approximately 6.1 billion tons of these "special" wastes (as defined by the Bevel amendment to HSWA) are generated annually.

Further, about 72,000 facilities generate about 7.6 billion tons of other industrial wastes each year (OSW, 1993a). These wastes are managed in 3,300 industrial landfills and at other on- and offsite management units. Information about many manufacturing wastes which include toxic organic and inorganic constituent is limited in many cases.

Finally, the evidence from National Priority List (NPL) listing determinations shows that even municipal landfills must be managed carefully to prevent risks since a number of them appear on the NPL. Approximately 209 million tons of municipal solid waste (MSW) are generated annually (OSW, 1995a); 127 million tons are managed in 3,600 MSW landfills in the U.S., and the remainder is combusted and recycled (OSW, 1996a).

Waste Combustion Facilities

In 1995, the United States incinerated approximately 48 million metric tons of municipal pathological, and hazardous wastes. Currently there are 211 municipal incinerators, 2,400 medical incinerators, 160 hazardous waste incinerators, 136 industrial furnaces, and 44 cement kilns burning waste materials in various U. S. locations.

Concerns have been raised about emissions from waste combustion facilities for a number of reasons: (1) these facilities can emit significant amounts of toxic contaminants such as dioxin, furans, mercury, lead, cadmium, and products of incomplete combustion, (2) these emissions become dispersed over large geographic areas that often include large populations or important food products (crops, animal, and dairy products), (3) exposure occurs over several pathways and routes, and (4)

high levels of contaminants emitted from waste combustion facilities (e.g., mercury) have been measured in environmental media surrounding waste combustion facilities.

While there is much scientific uncertainty about the actual risks from contaminants emitted from waste combustion facilities, the factors listed above are enough to influence public perception and the press that these risks are very high and unacceptable. Community protests at facilities such as Waste Technologies Incorporated (WTI) in East Liverpool, Ohio, and at many Superfund sites such as New Bedford Harbor, Massachusetts, and Bloomington, Indiana are examples.

Waste Management Costs

Waste management costs faced by the Nation are significant. It is estimated cost between $140 and $187 million per year for the hazardous waste combustion facilities to comply with by proposed Maximum Achievable Control Technologies (MACT) regulations. (OSW, 1995b & 1996b) The potential cost savings from implementing the proposed Hazardous Waste Identification Rule (HWIR) for Industrial Process Wastes which could exempt some low hazard wastes from Subtitle C requirements, are estimated at over $100 million annually. (OSW, 1995c)

Oils Spills and Leaking Storage Tanks

Spills and leaks of petroleum, petroleum products and non-petroleum oils are a serious problem affecting nearly every community in the United States. Oil releases threaten public health and safety through contamination of drinking water and through fire and explosions, diminish air and water quality, compromise agriculture, destroy recreational areas, waste nonrenewable resources, and cost the economy millions of dollars. Oil spills harm the environment by killing fish, birds, wildlife and biota; they destroy habitat and food and produce toxic effects in organisms and ecosystems.

Particular hazardous constituents of petroleum products have received attention because of their toxicity. They include benzene, MTBE (methyl-tertiary-butyl ether, a fuel additive intended to reduce carbon monoxide emissions from automobiles) and polynuclear aromatic compounds. Benzene is volatile and is a carcinogen. MTBE is considered a potential human carcinogen and is highly soluble, moves rapidly, and does not biodegrade. Several of the polycyclic aromatic hydrocarbons (PAHs) found in heavier petroleum hydrocarbon blends (e.g., fuel oils) are carcinogenic or mutagenic (IARC, 1989). The mobility, toxicity and biodegradability of PAHs varies depending upon the specific compound in this class.

The magnitude and complexity of the problem are reflected in our society's extensive reliance on petroleum, petroleum products and non-petroleum oils to fuel vehicles, heat buildings, generate electricity, produce food, and manufacture a wide variety of goods. The Department of Energy (DOE) reported that approximately 212 million gallons of

crude and 584 million gallons of refined petroleum products were produced in, imported to, or exported from the U.S. in 1994 (Energy Administration, 1995). Our continued national reliance on oil, the broad extent of its use, and the aging of our oil industry infrastructure suggest that oil spills and leaks will continue to be a serious problem in the future.

Much of the Nation's petroleum and chemicals are stored in underground storage tanks (USTs). At present, there are over 1.1 million active regulated USTs at over 400,000 sites across the U.S. Through September 1996, over 317,000 petroleum releases had been confirmed at about 40 percent of the 750,000 UST facilities in existence in 1990. EPA anticipates an additional 100,000 confirmed releases by the year 2000; 30,000 new releases are reported every year as owners and operators are complying with USEPA's 1998 requirements to upgrade, replace, or close substandard USTs. Besides petroleum, there are approximately 30,000 regulated USTs that store Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) hazardous substances.

EPA also regulates about 450,000 aboveground oil storage facilities for prevention, preparedness, and response purposes (OERR, 1991). These facilities each have from one- to several-hundred individual aboveground storage tanks (ASTs); each AST may contain between 661 and 10 million gallons. Petroleum oil and refined products are transported through approximately 1.9 million miles of oil and gas pipeline and 152,000 miles of liquid pipeline in the U.S. In addition, large and increasing amounts of non-petroleum oils are produced and widely used in the generation of electricity, in food processing, and in other industries throughout the country.

Annually, between 18,000 and 24,000 AST oil spills are reported to the National Response Center (NRC) and EPA Regions, and between 10 million and 25 million gallons are spilled per year (OERR, 1996a). Many of these spills were larger than 100,000 gallons in quantity; however, depending upon the location, small spills also can cause great ecological damage.

Hazardous Waste Remediation (Superfund)

Problems with our nation's *past* mismanagement of hazardous waste first gained widespread attention in the late 1970s. Incidents such as the contamination of Love Canal in Niagara Falls, New York, sparked widespread concern over hazardous wastes. In response to this growing concern, Congress passed the CERCLA in 1980. This law, commonly known as "Superfund", taxed the chemical and petroleum industries and provided broad federal authority to address the release or threatened release of hazardous substances that may endanger public health, welfare, or the environment. Over five years, $1.6 billion was collected in a trust fund for cleaning up abandoned hazardous waste sites. In 1986, the Superfund Amendments and

Reauthorization Act (SARA) was signed into law. SARA increased the trust fund to $8.5 billion over five years and strengthened EPA's authority to conduct cleanup and enforcement activities.

Waste Site Cleanup

EPA's Superfund program has screened hundreds of thousands of sites and release incidents. A measure of the immediacy of problems at sites is reflected in the work of the Superfund emergency response (removal) program. Nearly 4,300 emergency actions have been initiated to mitigate or eliminate immediate risks to human health and to prevent future risks (OERR, 1996b). These actions have reduced potential acute risks leading to death and injury, from explosions, fire, and toxic vapor clouds.

Approximately 40,000 sites have been identified as potential candidates for the federal Superfund remedial program (OERR, 1996b). Almost all these sites have been investigated as a result. To date, about 1,300 highest priority sites have been assigned to the National Priorities List (NPL), and additional sites are being studied to determine whether NPL listing is necessary. The NPL sites represent approximately 3 million acres in total area. The problem is not static; there continues to be a flow of new sites for states and/or the EPA to deal with. The size of this unaddressed problem was recently estimated by the General Accounting Office (GAO), which projected that a cap on the federal NPL might leave the states with 1400 to 2300 NPL-caliber sites to cleanup, at a total cost of 8.4 to 19.9 billion dollars (Sands, personal communication, 1996).

The seriousness of contamination at Superfund sites is exhibited by actions taken to remove populations from the immediate threat of contaminants at sites. The Superfund program has relocated, temporarily or permanently, almost 15,000 residents. It also has provided alternative drinking water supplies to approximately 350,000 people (OERR, 1996c).

Federal facilities represent another important class of waste disposal sites where serious contamination has been identified. An estimated 61,000 potential hazardous-substance release sites exist at over 2,000 federal facilities (CEQ, 1993).

Contamination at remedial sites involves substances of significant concern to EPA both because of their cancer and non-cancer hazards. For example, lead and PCB contamination are common problems addressed by the remedial programs. Unsafe concentrations of benzene, several chlorinated solvents, mercury, creosote, toluene, and other highly hazardous substances often are encountered. The Superfund program also confronts risks posed by substances such as DDT or chlordane that no longer are produced commercially but persist in the environment.

The existence of a hazardous contaminant in the environment does not in itself demonstrate an actual or potential threat to human health by exposure. Reasons for serious concern, however, are exemplified by a study by the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR estimates that about 11 million people live within one mile of the 1200 NPL sites studied (Williams and Lybarger, 1996). In addition, approximately 68 million people live within four miles of these NPL sites and approximately 65 percent of the sites have identified ground water contamination problems (Sands, personal communication, 1996)

Further, the Agency for Toxic Substances and Disease Registry (ATSDR), in its 1993-1995 report to Congress (ATSDR, 1996), states that:

> "Exposure assessment studies conducted by ATSDR during this reporting period show that some heavy metals, volatile organic compounds, and other specific substances occur at levels of health concern in the bodies of exposed people. Compounds such as lead, arsenic, mercury, polychlorinated biphenyls, and bromides are found at significant levels in people near some hazardous waste sites." This same report concludes: "Taking these health findings in the aggregate, ATSDR concludes that uncontrolled hazardous waste sites and unplanned releases of hazardous substances that constitute emergency events are a major environmental threat to human health. Although there remain significant gaps in the scientific database on the extent of human exposure to hazardous substances released from sites, and key toxicological data gaps still exist, progress has been made in better characterizing both the exposure and toxicity data bases. The human health finding accrued to date support the need for interdicting human exposure and mitigating toxicity of hazardous substances released from hazardous waste sites and similar sources of exposure."

EPA has defined an acceptable human health risk range for carcinogens (10-4 to 10-6 excess cancer risk) and a threshold of concern for non-carcinogens (hazard index of 1) for Superfund sites. At most Superfund sites, risks exceed acceptable levels, and action is taken. The cancer risk exceeded EPA's acceptable range in 80 percent of sites where decisions were made in 1991, and it exceeded 10-2 at approximately 25 percent of these sites. Another recent finding is that non-carcinogenic risk represents a very significant portion of the risk addressed by the Superfund program. The hazard index exceeded 1 at 75 percent of the 1991 sites for which decisions were made. At half of these sites, the hazard index was above 10, and at 15 percent of the sites it was above 100. Data from Superfund risk assessments completed from 1989 to 1995 at 380 Superfund sites show similar results. (Laws, 1996)

The costs of assessment and remediation of contaminated sites are large. The average cost of a Superfund site remediation is about $27M per site (USEPA, 1993a),

and at some sites the costs have been several hundred million dollars. A 1994 report by the National Research Council on ground water cleanup reviewed available data on the national cost of contaminated site remediation:

> "In part because of the wide variation in contaminated sites and because the total number of sites is uncertain, estimating the total national costs of cleaning up contaminated ground water is extremely difficult. One recent, widely publicized report concluded that over the next 30 years, the nation as a whole will spend $480 billion to $1 trillion, with a "best guess" of $750 billion, cleaning up . . . sites. (Russell et al., 1991). With 90 million households in the nation (Industrial Economics, Inc., 1991), this represents a cost of $8,000 per household. Another recent report concluded that by the year 2000, the nation will be spending nearly $24 billion per year complying with requirements for hazardous waste and underground storage tank cleanup under RCRA and site cleanups under CERCLA (Carlin et al., 1992, p. 38). Some contest the accuracy of such cost estimates because of the high level of uncertainty associated with the magnitude of the contamination problem and the large number of assumptions underlying the estimates. Nevertheless, the potential enormity of the costs has fueled the debate about whether the benefits the nation will receive from ground water cleanup at hazard waste sites justify the costs." (NRC, 1994)

It has been shown that improved site characterization can reduce cleanup costs by millions of dollars, by better defining the volumes of soils that really need to be remediated. At a site in Missouri, $6M was saved because an improved ORD sampling design for the site more accurately defined the location of significant contamination. Similarly, it has been shown that millions of dollars can be saved by the application of innovative remediation technologies. A survey of 17 sites which applied innovative technologies of the type tested in the EPA Superfund Innovative Technology Evaluation (SITE) program showed that an average of $21M was saved at each site when compared to the cost of using conventional cleanup technologies.

Accidental Releases

In 1995, approximately 17,000 accidental release reports involving chemicals were made to the National Response Center (NRC, 1996). These accidents may occur at many points during the life cycle (e.g., production, use, and disposal) of a given chemical. For example, accidents may result during the transport of a chemical, in the manufacturing process, or while the chemical is being employed as an end product.

As a way of understanding the magnitude of the problem, the National Environmental Law Center has calculated "worst case scenarios" for accidents involving approximately

10,000 U.S. manufacturing companies. They have concluded that close to 45 million Americans live in zip codes containing facilities with vulnerable zones extending outward more than three miles from the facility (National Environmental Law Center, 1995) and this analysis may underestimate potential exposure, since it does not address, for example, populations vulnerable to accidents that occur in transportation.

Chemical releases at fixed facilities most frequently reported to the NRC involve, in order of frequency: PCBs, anhydrous ammonia, sulfuric acid, and chlorine. In transportation, the most frequently reported accidental releases, in order, involve: corrosive liquids, flammable liquids, compound cleaning liquid, gasoline, and hydrochloric acid solution (U.S. EPA, 1993b).

Waste Research Program Mission and Goals

Mission Statement

The mission of the ORD Waste Research Program is to:

- **Perform research and development** to identify, understand, and solve current and future problems related to the handling and disposal of hazardous wastes and the characterization and remediation of contaminated waste sites.

- **Interpret and integrate scientific information** to help organizations at all levels make better decisions about handling and treatment of hazardous wastes.

- **Provide national leadership** in addressing emerging hazardous waste issues and in advancing the science and technology of risk assessment and risk management as they relate to hazardous wastes.

Waste Research Goals

The five scientific and technological goals of this research plan are:

- To advance the science of risk assessment to support hazardous waste management and remediation of contaminated sites, including:

    - Understanding the effects of exposures to hazardous wastes on human health and ecological systems.
    - Developing processes for predicting and measuring exposure to humans and ecological systems, and uncovering the processes leading to those exposures.
    - Estimating risk and characterizing and communicating those estimates.

- To develop, demonstrate, and evaluate more cost-effective, innovative technologies for control of hazardous wastes, site characterization, and remediation.

- To advance the science of monitoring and predicting environmental concentrations and effects, as well as the fate and transport of toxic material.

- To provide technical assistance to ensure that innovative approaches to site assessment, characterization and remediation are applied in the field in a consistent and effective manner.

- To play a leadership role in areas of ORD capability by providing, developing, and maintaining a highly respected research program which is well connected with stakeholders.

Relationship to Agency Goals

Recently Congress passed the Government Performance and Results Act (GPRA) that requires each agency to submit an annual performance plan covering each program activity set forth in the agency's budget. In response to GPRA the EPA developed a Planning, Budgeting, Analysis, and Accountability (PBAA) Organization. Part of the process put in place by this organization was the development of programmatic goals, objectives and subobjectives. OSWER has developed a "Safe Waste Management" goal that has two objectives (one on contaminated waste sites and one on waste management) for which ORD has developed subobjectives. These are:

- ORD Safe Waste Subobjective: 1.1 - Contaminated Sites - Ground Water and Soils.
- ORD Safe Waste Subobjective: 2.1 - Active Waste Management and Combustion Facilities.

Relationship to ORD's Strategic Plan

The ORD has recently developed a process for the strategic planning of research that follows the risk assessment paradigm (effects, exposure, risk assessment, and risk management) (see Figure 1-1) and uses three sets of criteria for setting research priorities (ORD, 1997). This strategic approach (Figure 1- 2) calls for the development of "science research plans" for each selected research topic which will:

- Describe the major research components and directions we will pursue over the next few years.

- Describe how these components fit into the risk assessment/risk management paradigm.

- Delineate the major outputs expected to be produced over the next three years.

The ORD Strategic Plan also identifies general goals, long-term objectives, and activities to meet these objectives. The Waste Research Strategy is consistent with, and builds upon, these goals and objectives.

Prior Research Strategies

Previously, a number of research plans/strategies related to hazardous waste have been produced. The most current and important is the one developed by the Committee on the Environment and Natural Resources (CENR).

CENR National Strategy

The President's National Science and Technology Council through its Committee on the Environment and Natural Resources developed and published *A National R&D Strategy for Toxic Substances and Hazardous and Solid Waste,* in September of 1995 (CENR, 1995). This is the first consensus federal "framework" for research in this area. Appropriate portions of this framework have been adopted for the Waste Research Plan, making it consistent with the research needs and strategic directions identified in the CENR strategy.

The CENR strategy has adopted "risk" as the organizing theme. Consequently, the three sections of that strategy are: 1) Risk Assessment, (2) Managing Risks from Toxic Substance and Wastes, and (3) Social and Economic Aspects of Risk Management. Each of these is further divided as shown below:

Risk Assessment
- Hazard Assessment
- Exposure Assessment
- Risk Characterization

Risk Management
- Pollution Prevention
- Control
- Remediation
- Monitoring

Social and Economic Aspects of Risk Management

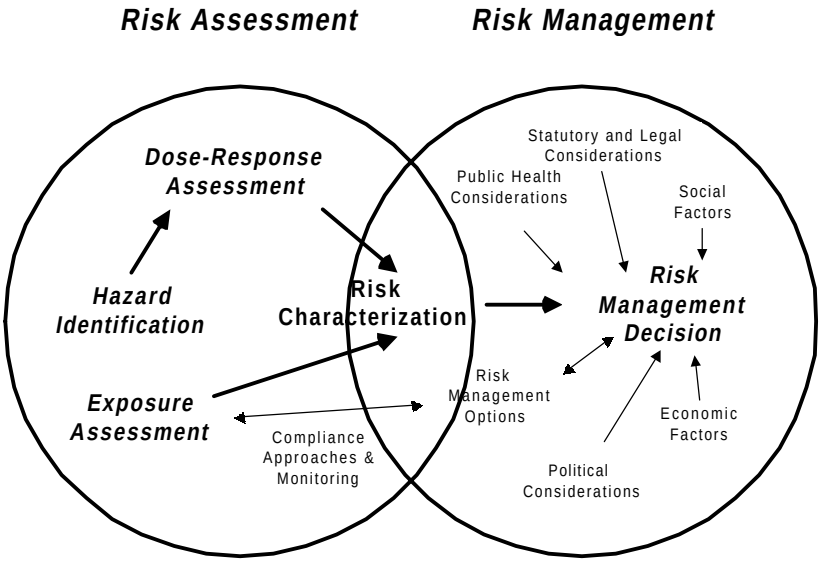
For each of the three major sections the strategy discusses a conceptual framework, the current state of understanding, research priorities, and a set of milestones for 1995 - 1999.

The ORD Waste Research Strategy utilizes the CENR risk paradigm structure in organizing the discussion of research needs and proposed research activities. Also, the CENR report is one source of research needs addressed by the Strategy.

ORD Strategic Issue Plans

During the early 1990's, ORD changed its research planning process from a media/program office focus (e.g., Air, Water, Pesticides/Toxics, etc.) to an environmental issue focus. The four issue plans most relevant to the current waste research planning activity are the Hazardous Waste Issue Plan (ORD, 1993a), the Surface Cleanup Issue Plan (ORD, 1993b), the Bioremediation Issue Plan (ORD, 1993c), and the Ground Water Issue Plan (ORD, 1993d). The organizing principles and the research priorities from these plans are summarized in Appendix A, Table A-1. Review of this table indicates general agreement on the research topics and their relative priorities.

The Risk Assessment Paradigm



Adapted from:

Risk Assessment in the Federal Government: Managing the Process . National Academy of Sciences. 1983.

Science and Judgment in Risk Assessment. National Research Council. 1994.

Figure 1-1. Risk Paradigm Used by the Office of Research and Development (Source: ORD, 1997).

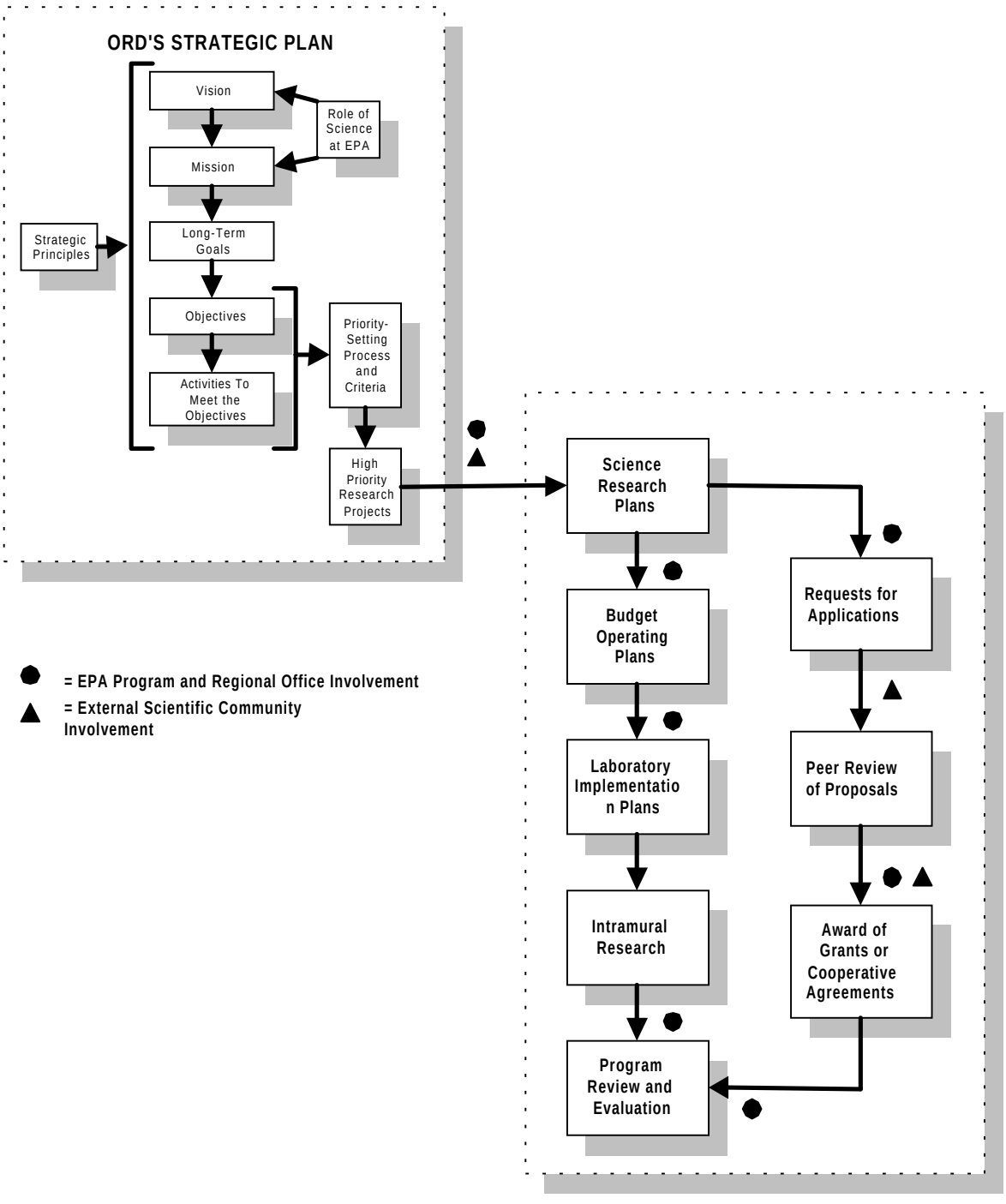


Figure 1-2. Translating ORD's Strategic Plan Into a Research Plan (Source: ORD, 1997).

Chapter 2
Setting Research Priorities

Research needs invariably exceed resources available to support them, and decisions must be made about which needs to pursue. The purpose of this section is to describe: 1) how the selection and prioritization of waste research fits into ORD's strategic planning approach, 2) what the waste research needs are, 3) how waste research priorities were developed, and 4) what the resulting priorities are.

Process for Ranking Research

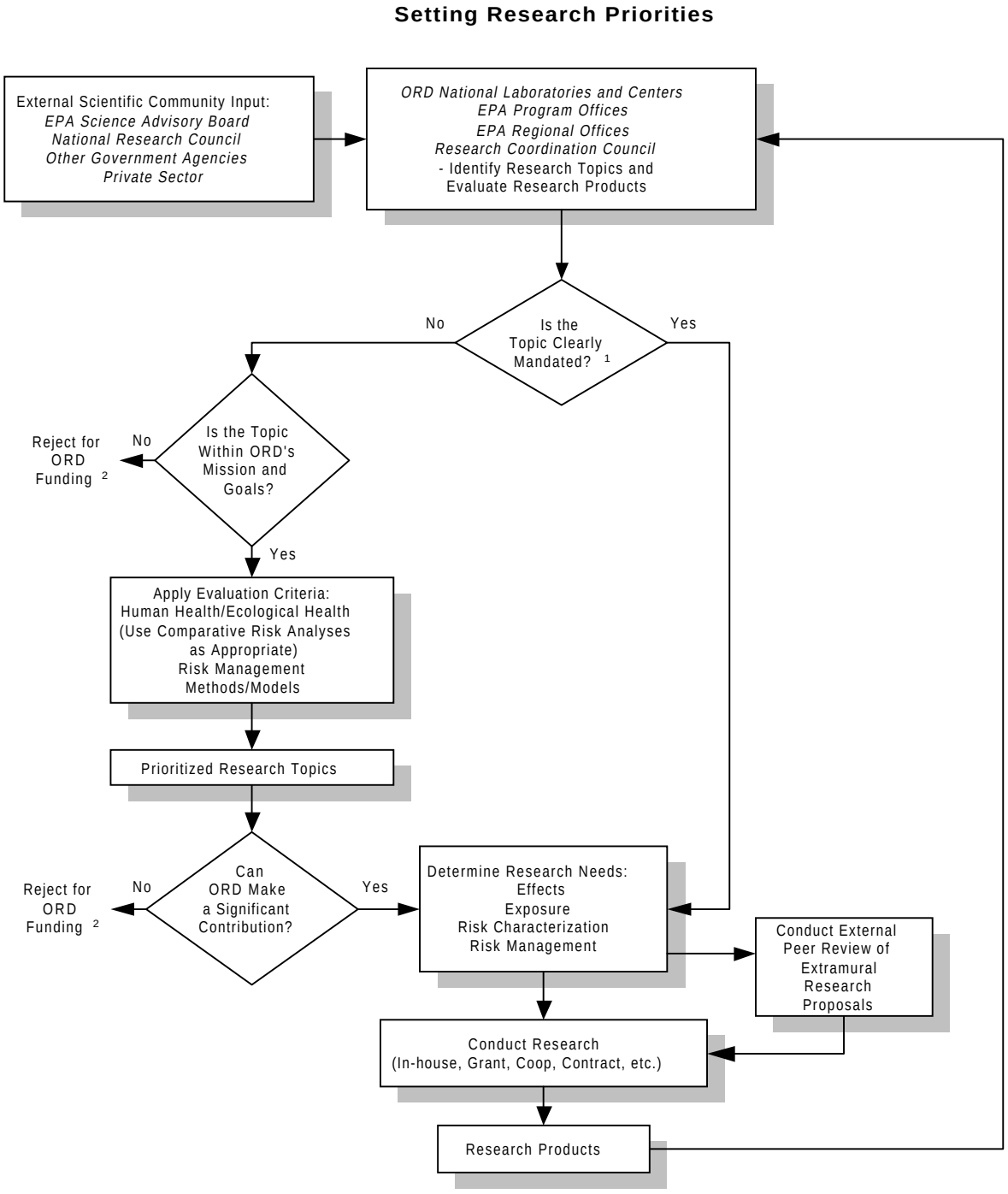
The ranking of waste research builds upon ORD's Strategic Plan (ORD, 1997) by refining the priority setting process and adding some additional criteria based upon waste-specific strategic considerations.

ORD Strategic Planning Process

In ORD's Strategic Plan (see Figure 2-1), potential research topics are evaluated by determining if they are mandated (by legislation, Congress, or the courts) and if they are consistent with ORD's mission and goals. Topics that remain are prioritized and a determination made as to whether ORD is scientifically capable of making a significant research contribution to these research areas. The three sets of criteria for evaluating and ranking potential research topics are: Human Health and Ecological Health Criteria, Methods/Models Criteria, and Risk Management Criteria.

Waste Research Strategic Planning Process

To facilitate the identification and ranking of waste-specific research, the ORD developed a process called the Waste Research Ranking Scheme shown in Figure 2-1. ORD first identified waste research needs based on several sources. This resulted in a lengthy list of needs of varying degrees of specificity. Preliminary determinations were made on who should most appropriately address these needs, be it another federal agency, other ORD research programs or the ORD Waste Research Program itself. Based on an evaluation of these research needs and a long history of conducting waste related research, ORD identified major waste-related environmental problems which the Office could address and defined these as "research topic areas." The research topic areas selected in the Waste Research Strategy are: Contaminated Sites - Ground Water, Contaminated Sites - Soil/Vadose Zone, Emissions from Waste Combustion



[1] If so, EPA may have no discretion to reject or delay this research.
[2] EPA program offices and regions may still choose to fund, using ORD labs, grants, contracts, etc., or a research source outside of ORD.

Figure 2-1. Office of Research and Development Strategic Planning Process (Source: ORD, 1997).

Table 2-1. ORD Criteria for Evaluating and Ranking Potential Research Topics

Human Health and Ecological Health Criteria	Methods / Models Criteria	Risk Management Criteria
• What type of effect would the research investigate / mitigate and how severely might this effect impact humans or ecosystems? • Over what time scale might this effect occur? • How easily can the effect be reversed, and will it be passed on to future generations? • What level of human or ecological organization would be impacted by the effect? • On what geographic scale might this effect impact humans or ecosystems?	• How broadly applicable is the proposed method or model expected to be? • To what extent will the proposed method or model facilitate or improve risk assessment or risk management? • How large is the anticipated user community for the proposed method or model?	• Have the problem's source(s) and risk been characterized sufficiently to develop risk management options? • Do risk management options (political, legal, socioeconomic, or technical) currently exist? If so, are they acceptable to stakeholders, implementable, reliable, and cost-effective? • Could new or improved technical solutions prevent or mitigate the risk efficiently, cost-effectively, and in a manner acceptable to stakeholders? • Are other research organizations (e.g., agencies, industry) currently investigating / developing these solutions or interested in working in partnership with ORD on the solutions?

Waste Research Ranking Scheme

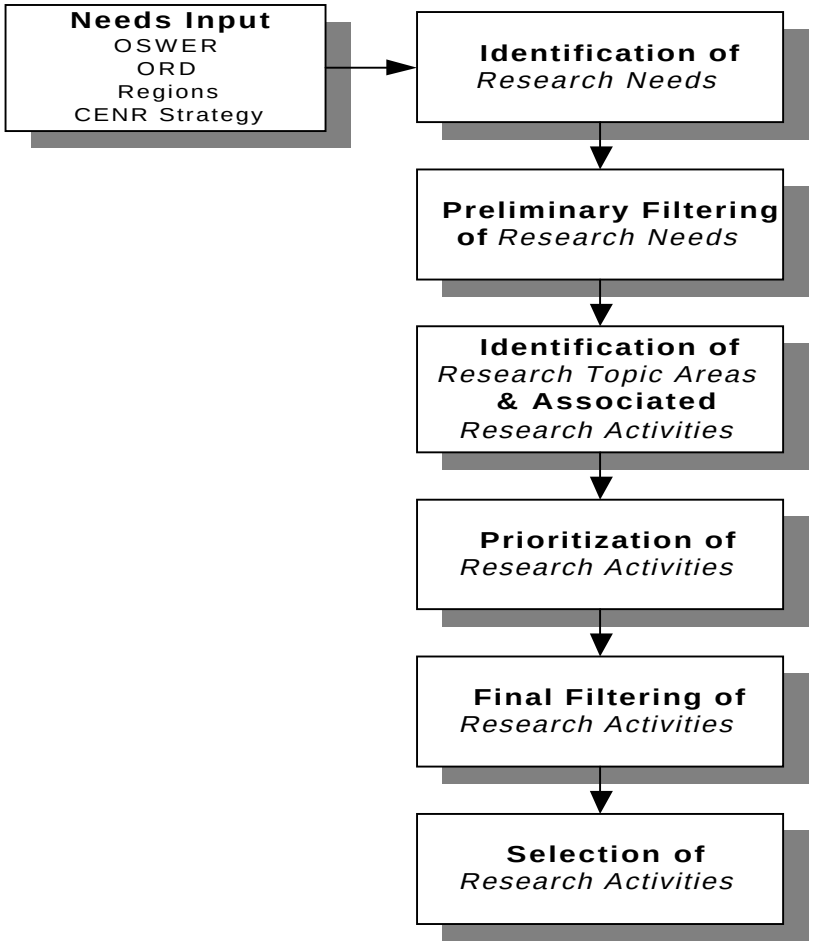


Figure 2-2. ORD Waste Research Ranking Scheme

Facilities, and Active Waste Management Facilities. All of these research topic areas are discussed in detail later in this section. For each research topic area, ORD identified a set of "research activities" that needed to be carried out to fully address uncertainties associated with the particular environmental problem. These research activities were evaluated and ranked within each research topic area using the same three sets of criteria identified in Table 2-1.

Throughout this process, research needs and research activities were organized using a slight modification of the risk paradigm organizing principles from the CENR strategy. Six of the CENR categories were used: three were risk assessment categories: hazard assessment, exposure assessment, and risk characterization and the other three were risk management categories: control/management, remediation, and monitoring. Pollution Prevention and Social and Economic Aspects of Risk Management were not used since they are outside the scope of this research plan.

Before the final selection of research activities, a filtering process occurs that determines whether a given research activity is appropriate for a particular ORD Laboratory or Center (i.e., is it consistent with the Laboratory's or Center's mission and goals) and whether the Laboratories or Centers have the capability (core scientific staff) and / or capacity (staff, facilities, equipment, and infrastructure) to make a significant scientific contribution.

Application of the Waste Ranking Scheme

The purpose of this section is to describe what research needs were identified, how the research priorities were developed, and what the resulting priorities were. The multi-step approach to waste ranking is outlined in Figure 2-1 and discussed below.

Identification of Research Needs

Research needs were identified from three sources: 1) those identified by the CENR that were relevant to the EPA's mission; 2) those identified by the individual Program Offices: (Office of Solid Waste (OSW), Office of Emergency Response and Remediation (OERR), Technology Innovation Office (TIO), Office of Underground Storage Tanks (OUST), and Chemical Emergency Preparedness and Prevention Office (CEPPO), as well as the EPA Regional Offices; and 3) the ORD. The majority of these research needs were identified through numerous interactions between ORD and the various OSWER offices over the last several years and are primarily based on material provided by OSWER at ORD's most recent Annual Waste Research Program Review (December 1996).

A summary of research needs from all three sources is provided in Appendix B.

The OSWER and Regional research needs are summarized in Table 2-2 below. Generally, OSW identified hazardous waste combustion, multimedia science, waste technology, and pollution prevention / derived waste products as their four highest priority areas. They also identified as high priority: human health sciences, ecological risk, socioeconomic, methods, and technical assistance for corrective action. OERR's highest priorities for support and research have consistently been: site-specific technical support, risk assessment support, innovative site characterization technologies, and site remediation / cleanup technologies. Research priorities from OUST are limited to corrective action since oversight of this program is systematically being delegated to the states. The Technology Innovation Office (TIO) has identified priorities related to continuation of the Superfund Innovative Technology Evaluation (SITE) Program, and research in the areas of bioavailability, and natural attenuation. The Chemical Emergency Preparedness and Prevention Office (CEPPO) has identified research related to the accidental large-scale release of gases and liquids and support of the DOE spills facility in Nevada. The Regional Offices' research generally mirrors the Program Office needs. However, they have identified needs related to indirect exposure from waste combustion, natural attenuation, development of measurement and risk assessment tools, site-specific technical support and training courses and seminars as their highest priorities.

Table 2-2. Summary of Major Program Office and Regional Research and Support Needs

Program Office	Higher Priority Needs	Medium Priority Needs	Lower Priority Needs
OSW	Hazardous Waste Combustion - Dioxin/Furan Emissions - Surrogates and CEMs for HAPs, Dioxins, and Furans - Technical Support for Combustion Issues - Speciation Methods for PICs - Air Deposition Models - Indirect Exposure -- Bioaccumulation through the Food Chain - Plus others	Human Health Sciences - IRIS/HEAST Data Base Updates - Alternative Endpoints - QSAR/SAR Methodology Development Ecological Risk - Ecotoxicity Screening Levels, Bioavailability Mechanisms - Improved Screening Tools	
	Multimedia Science - Improve Multimedia Models and Data Bases - Validation / Verification of Fate and Transport Models (Multimedia and Indirect Exposure Portions) - Subsurface Biodegradation Rates - Enhance Subsurface Models to Include Fractured Flow - Plus others	Socioeconomic - Risk Tolerance Thresholds for Exposed Populations - Engineering/Costing Support - Contingent Valuation	
	Waste Technology - Stability / Bioavailability of Constituents in Waste Derived Products - Chemistry of Waste Leaching -- Improve TCLP - Treatment Alternatives for Mercury - Efficacy of Waste Solidification / Stabilization Technologies - Natural Attenuation, Permeable Reaction Barriers - Innovative Site Characterization Technologies - Plus others	Methods - Speciation of Arsenic and Selenium - Pesticide Methods Development (GC/AED) - PAHs by Capillary Electrophoresis Technical Assistance for Corrective Action	

Program Office	Higher Priority Needs	Medium Priority Needs	Lower Priority Needs
	Pollution Prevention / Waste Derived Products - Source Reduction / Recycling for Processes that Generate the Most Toxic Wastes - Technologies for Reducing Barriers to Recycling - Source Reduction for Combustion Wastes - Plus others		
Regions (RCRA Needs)	- Particle Size Distribution Testing Methods Development in Support of Air Modeling - Develop Ecological Risk Screening Values for Various Exposure Scenarios - Natural Attenuation for Chlorinated Solvents	- Improve the Total Organic Emission (TOE) Test Methods - Enhance Dry Gas Air Dispersion Models - Enhance Guidance on Synergistic Effects When Deal with Mixtures (Low Priority) - Fill Data Gaps in IRIS and HEAST Databases - Ecological Toxicity Mechanisms of Action for Endocrine Disruptors - Improved Biotransfer and Uptake Factors for Risk Assessments - Modify TCLP to Address Oily Wastes - Develop a Test for Corrosivity of a Solid - Develop a Test for Ignitability of a Solid - Develop a Test of Evaluate to Permanence of Stabilized Wastes	
OERR	Site Specific Technical Support - Technical Support Centers - Environmental Photographic Interpretation Center (EPIC) - START - Center for Exposure Assessment Modeling (CEAM) - Establish a Technical Support Center for Ecological Risk Assessment - Technology Transfer -- Seminars and Courses - Program Office Support -- Presumptive Remedies, Soil Screening, etc. - Technology Transfer - ATTIC, etc.		

Program Office	Higher Priority Needs	Medium Priority Needs	Lower Priority Needs
	Site Remediation Research - Ground Water Containment - DNAPL Remediation Methods - Subsurface Reaction Walls - Phytoremediation Oil Spills Research - Technical Correction on Swirling Flask Test for Dispersants - Develop Surface Washing Effectiveness Test	Oil Spills Research - Develop Bioremediation Strategies - Ecological Impacts of Countermeasures	
	Site Characterization Research - Ground Water DNAPL Characterization - Natural Attenuation/i*n situ* Bioremediation Site Characterization and Process Research - Ground Water Modeling	Site Characterization Research - Analytical Methods for Bioaccumulative Chemicals - Analytical Methods and QA for Complex Mixtures	
	Risk Assessment Research - Ecological Significance - Benefits versus Habitat Destruction - Dermal Toxicity Values - Bioavailability of Metals and Organics - Soil - Improved Exposure Assessment - Improved Dose-Response Assessment - Pb Uptake / Models - Dermal Exposure Model	Risk Assessment Research - Weight of Evidence Approach for Ecological Effects Cleanup Levels	
Regions (Superfund Needs)	- Site-specific Technical Support - Training Courses and Seminars - Remediation Design and Field Construction Support - Develop Alternative Approaches using Immunoassay and Bioassay Tools - Develop Ecologically-based Screening Values		
OUST	- Natural Attenuation - MTBE Treatment - Fate and Transport Models for Risk-based Corrective Action		

Program Office	Higher Priority Needs	Medium Priority Needs	Lower Priority Needs
TIO	Superfund Innovative Technology Evaluation (SITE) Program - Remediation Technologies - Monitoring / Characterization Technologies Consortium for Site Characterization Technologies Bioavailability of Families of Contaminants Metrics for Evaluation of *In situ* Technologies Models to Predict the Efficacy of Natural Attenuation		
CEPPO	-Support DOE Spill Test Facility Hazard Analysis Support - Large-scale Releases of Gases and Liquids		

Preliminary Filtering of Research Needs

A preliminary filtering of these research needs was conducted to identify Congressionally mandated research programs and to identify other research programs established by Congress to conduct certain types of Superfund related research.

Applying these filters identified research needs or activities that are authorized by legislation for explicit ORD attention. They are the Superfund Innovative Technology Evaluation (SITE) Program and the Hazardous Substance Research Centers (HSRCs). The SITE program is coordinated closely with OSWER's Technology Innovation Office, and involves the demonstration and verification of the performance and cost of new, innovative monitoring and remediation technologies. The HSRCs are research grants to a selected number of regionally located consortia of academic institutions that each conduct waste related research in a specific area.

ORD does not determine the specifics of the HSRC remediation research program activities and, therefore, the HSRCs are not considered further in this section. They are described in Appendix C**.**

In addition, CERCLA and SARA mandate that the Agency for Toxic Substances and Disease Registry (ATSDR) performs health assessments (epidemiology-type studies) at waste sites to evaluate whether exposure has occurred and the potential impact of that exposure, so these kinds of investigations have been filtered out of the ORD list of research needs. Also, CERCLA mandates ATSDR to ensure the initiation of an applied substance-specific research program, to fill data gaps identified in ATSDR-developed toxicological profiles, so ORD does not view this type of research as appropriate for a major focus.

CERCLA and SARA further mandate that the National Institute of Environmental Health Sciences (NIEHS) establish and maintain a university-based, basic research program. The NIEHS basic research program is a multi-disciplined program which conducts research in the following topics: (1) detection of hazardous substances in the environment, (2) evaluation of health effects, (3) assessment of risk, and (4) methods to remediate sites. The program which is now completing its tenth year, provides about $30 million of funding to 17 programs at 69 universities and institutions throughout the United States. The NIEHS mandate filters out what ORD might consider "basic" research studies from consideration in its waste research program. In practice the NIEHS mandate for basic research is not a major filter, because ORD, recognizing that often what is basic or applied is in the eye of the beholder, nevertheless considers all of its research to have an applied rationale. On the other hand, while no specific research needs or scientific questions are mandated for NIEHS, the size and human health focus of the NIEHS program are significant factors in tilting the ORD research focus towards risk management versus risk assessment, especially for human health research.

Many important waste sites have nuclear wastes or mixed nuclear and non-nuclear wastes and/or other defense-related or energy-related wastes. Because of the magnitude of their respective programs, ORD views these issues as largely the responsibility of the Department of Defense (DOD) and the Department of Energy (DOE) to address. Research to address these kinds of waste is consequently not an explicit focus of the ORD research described here. Nevertheless, it is important to note that ORD does participate in collaborative research with these organizations (and others) when it satisfies their joint priorities. For example, ORD has participated actively in the Defense Department's Strategic Environmental Research and Development Program (SERDP) when it can further its ability to address research needs. Appendix C describes the remediation research programs of other Federal agencies in more detail and also lists other ORD research programs with contacts.

Identification of Research Topic Areas and Associated Research Activities

In order to facilitate a relative ranking process and to provide a better focus for EPA research efforts, several organizing steps were taken.

First, a conceptual structure was established after an examination of the research needs (see Appendix B for details). Four broad research topics areas were established which represent the major problems EPA/ORD waste research will address. The four areas and the reasons for selecting them are:

Contaminated Sites - Ground Water: Ground water has been contaminated by a large number of releases to the environment. In 1994, the NRC estimated that the number of hazardous waste sites that are likely to have ground water contamination ranges from 300,000 to 400,000. While only a small fraction of ground water is contaminated, it is generally near populations centers and is at shallow depths, which make it the most economical to use as a drinking water supply. Large uncertainties remain in our ability to characterize the subsurface especially with respect to the suitability of sites for natural attenuation and sites contaminated with NAPLs, and current remediation technologies are not always effective and are very expensive. In addition to being the most difficult media to characterize and remediate, ground water is also the slowest resource to naturally recover (decades to centuries). These are some of the reasons that ground water is a high-priority research topic area.

Contaminated Sites - Soils/Vadose Zone: The complexity and heterogeneity of soil/vadose zone matrices present a large number of technical challenges to their assessment and remediation. (The vadose zone is the unsaturated zone above the ground water table and the soil surface.) There are numerous uncertainties associated with soil/vadose zone decisions and the cost of their remediation is still quite high (an average of $27M per Superfund site in1993). Local risks to humans

and ecosystems, high costs and uncertainty in decision making are all reasons for needing contaminated soil/vadose zone research.

Emissions from Waste Combustion Facilities: Currently, there are 307 municipal waste combustion facilities with a capacity of 104,000 tons per day. About 30 million people in 35 states and 900 communities are served by municipal waste combustion facilities. This accounts for approximately 16 percent of the waste generated annually. In addition to large municipal waste combustion facilities, there are thousands of small incinerators such as those used to dispose of medical wastes. There are also several hundred facilities that burn hazardous wastes or are being used in contaminated site remediation. All of these facilities have the potential to emit toxic contaminants such as dioxin, furans, cadmium, lead, and mercury.

Active Waste Management Facilities: A total of 400,000 facilities have reported generating RCRA hazardous waste in the U.S. About 200 million tons of hazardous waste are generated each year by the largest generators. While far fewer are active today, historically more than 5,000 facilities have been involved in the treatment, storage and disposal of hazardous waste.

Second, research activities were then identified that would address the major research needs within each topic area. The research activities for each of the four research topic areas are summarized in Table 2-3. Their relative ranking within each research topic area is also given.

A fifth topic area -- technical support -- was identified to be included in ORD's waste research program. Needed technical support activities were also identified. Since these activities could not be prioritized with research activities using the risk paradigm, they are discussed at the end of this chapter and in Appendix H.

Prioritization of Research Activities

Ordinal rankings were developed using the three sets of ranking criteria identified in the ORD Strategic Plan (see Table 2-1) for individual research activities within each research topic area. Research activity rankings were first developed based on science criteria only. Uncertainty in risk assessment, efficacy and cost-effectiveness of risk management technologies, and the broad applicability of methods and models were the primary criteria in establishing the science ranking (see the description of the ranking criteria in the previous section). These criteria were used for establishing priorities according to the three simplified graphic representations shown in Figure 2-3. Those research activities that fall within the upper right hand corners were considered to be high priority, those that fall in the top left and bottom right corners were considered medium and those that fall in the lower left corners were considered low. The final rankings (shown in parentheses next to each research activity in Table 2-3) also considered a number of other non-science factors (this final ranking is referred to as the “Science Plus” ranking). Examples of these other factors include such items as: an

administration priority; a CENR research priority; a Program Office priority; regulatory or legal mandates; priorities in Agency; Congressional directives; and FY98 area for new funding.

Final Filter of Research Activities

In addition to filtering out research it considers more appropriate to other federal organizations, ORD's Waste Research Strategy also filters out research that: 1) it considers more appropriate for or is being conducted by other research programs within ORD; or 2) does not fall within the mission, goals and/or expertise of a particular ORD Laboratory or Center. Many of the research needs identified for the Waste Research Program are relevant to all or most EPA's regulatory programs. Many of these research needs are addressed more appropriately by the multimedia-based research programs in ORD, for which research plans are either developed or are in preparation. For example, research to improve the risk assessment process, including effects, exposure and assessment research, is important to all EPA programs, and is described in the ORD Human Health Risk Assessment Research Plan (ORD, 1997d) and the Ecological Research Strategy (ORD, 1997e). Similarly, research on pollution prevention is supported by a multimedia program and described in its own Pollution Prevention Research Plan (ORD, 1997b).

The research activities filtered out of the Waste Research Program in this final process are:

- Ecosystems Effects
  - Rationale: This research is more appropriately addressed as part of ORD's Ecosystem Protection Research Program.
- Chemical Toxicity Testing for Human and Ecological Endpoints
  - Rationale: This work is the routine application of standard toxicology protocols for the development of human and ecological toxicity values and is not considered a priority use of the limited ORD staff and facilities. This work might best be conducted by OSWER, possibly through NIEHS National Toxicology Program.

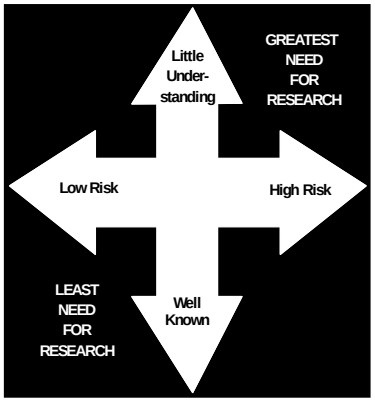
Selected Waste Research Activities

Table 2-4 presents the remaining research activities addressed by the Waste Research Strategy. This table shows the Science Plus ranking of these waste research activities. This ranking is a consensus ranking arrived at in discussions amongst ORD, OSWER and Regional representatives.

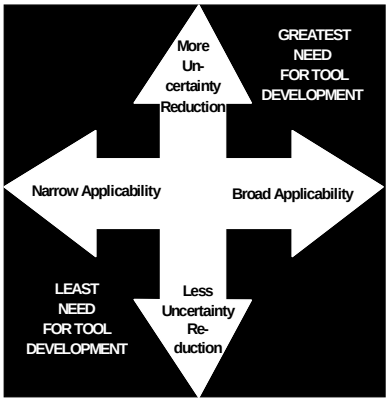
Table 2-3. Research Activities Displayed by Research Topic Areas and the Risk Paradigm Categories.

Research Topic Areas (In Priority Order)	RESEARCH ACTIVITIES BY RISK PARADIGM CATEGORIES					
	Risk Assessment			*Risk Management*		
	Exposure Assessment	Hazard Assessment	Risk Characterization	Remediation & Restoration	Control	Monitoring
Contaminated Sites - Ground Water	- Environmental Fate and Transport Modeling (4)* - GW Exposure Factors / Pathways (9)	- Mixtures Toxicology (12) - Ecosystem Effects (13) - Ecological Risk Assessment Methods (14) - Human Dose-Response Models for Mixtures (2)		- Natural Attenuation (1) - Abiotic Treatment of GW (5) - Biotreatment of GW (7) - Containment of GW (8) - Demonstration / Verification of Innovative Remediation Technologies (10)		- Subsurface Characterization (3) - Field and Screening Analytical Methods for GW (6) - Demonstration / Verification of Field Monitoring Technologies (10)
Contaminated Sites - Soils / Vadose Zone	- Estimating Human Exposure & Delivered Dose (1) - Estimating Soil Intake and Dose - Wildlife Species (2)	- Screening Tests to Measure the Effectiveness of Treatment (6) - Mixtures Toxicology (12)		- Biotreatment of Soils (2) - Containment of Soils (6) - Demonstration / Verification of Innovative Remediation Technologies (9) - Abiotic Treatment of Soils (11) - Oil Spills (13)		- Field Sampling Methods (4) - Field and Screening Analytical Methods for Soils (5) - Sampling Design (8) - Demonstration / Verification of Field Monitoring Technologies (9)
Emissions from Waste Combustion Facilities	- Indirect Exposure Characterization / Modeling (1) - Indirect Pathway Risk Assessment Methods (3)	- Movement of Bioaccumulative Chemicals in Food Webs (6) - Dose-Response of Key Contaminants (5)			- Emissions Prevention and Control (1)	- Continuous Emissions Monitoring (CEMs) Methods (4)
Active Waste Management Facilities	- Multimedia, Multipathway Exposure Modeling (1) - Environmental Fate and Transport, Physical Estimation (3)	- Chemical Toxicity Testing for Human and Ecological Endpoints (6) - Developing Provisional Toxicity Values for Contaminants (2)			- Waste Management (5)	- Waste Characterization and Sampling (4)

* Equals the ordinal rank of each research activity within a specific Research Topic Area based on the science plus ranking factors.



Setting Priorities for Effects, Exposure, and Assessment Research



Setting Priorities for Methods & Models Research

Setting Priorities for Risk Management Research

Source: Adapted from Paul Slovic, *Risk Perception*

Figure 2-3. Setting Research Priorities

Table 2-4. Selected ORD Waste Research Activities

Research Topic Areas (In Priority Order)	RESEARCH ACTIVITIES BY RISK PARADIGM CATEGORIES					
	Risk Assessment			*Risk Management*		
	Exposure Assessment	Hazard Assessment	Risk Characterization	Remediation & Restoration	Control	Monitoring
Contaminated Sites - Ground Water	- Environmental Fate and Transport Modeling (7)* - GW Exposure Factors / Pathways (21)	- Mixtures Toxicology (26) - Ecological Risk Assessment Methods (38) - Human Dose-Response Models for Mixtures (3)		- Natural Attenuation (2) - Abiotic Treatment of GW (9) - Biotreatment of GW (16) - Containment of GW (17) - Demonstration/ Verification of Innovative Remediation Technologies (27)		- Subsurface Characterization (6) - Field and Screening Analytical Methods for GW (5) - Demonstration/ Verification of Field Monitoring Technologies (27)
Contaminated Sites - Soils / Vadose Zone	- Estimating Human Exposure & Delivered Dose (1) - Estimating Soil Intake and Dose - Wildlife Species (3)	- Ecological Screening Tests to Measure the Effectiveness of Treatment (18) - Mixtures Toxicology (34)		- Biotreatment of Soils (3) - Containment of Soils (18) - Demonstration/ Verification of Innovative Remediation Technologies (27) - Abiotic Treatment of Soils (31) - Oil Spills (36)		- Field Sampling Methods (8) - Field and Screening Analytical Methods for Soils (9) - Sampling Design (22) - Demonstration/ Verification of Field Monitoring Technologies (27)
Emissions from Waste Combustion Facilities	- Indirect Exposure Characterization/ Modeling (13) - Indirect Pathway Risk Assessment Methods (11)	- Movement of Bioaccumulative Chemicals in Food Webs (33) - Dose-Response of Key Contaminants (24)			- Emissions Prevention and Control (12)	- Continuous Emissions Monitoring (CEMs) Methods (23)
Active Waste Management Facilities	- Multimedia, Multipathway Exposure Modeling (14) - Environmental Fate and Transport; Physical Estimation (25)	- Developing Provisional Toxicity Values for Contaminants (18)			- Waste Management (36)	- Waste Characterization and Sampling (32)

* Equals the ordinal rank of each research activity across the entire Waste Research Program based on the science plus ranking factors.

Ranking Research Activities Within Research Topic Areas

The following sections briefly describe each of the Research Topic Areas, the scientific and technical uncertainties associated with them, and the rationale for the relative rankings of the research activities within each topic area.

Ranking Research on Contaminated Sites - Ground Water

Ground water has been contaminated by a large number of releases to the environment. In 1994, the National Research Council (NRC) estimated that the number of hazardous waste sites that are likely to have ground water contamination ranges from 300,000 to 400,000. The majority of this contamination is caused by leaking USTs, but a recent OSWER white paper indicates that up to 40,000 sites are potential candidates for the federal Superfund program and historically about 80 percent of Superfund sites have ground water contamination. The NRC assessment includes estimates of ground water contamination at RCRA facilities (1,500-5,000 sites), federal facilities (10,000-12,000 management units) and 20,000-40,000 state sites.

In the past, concerns about contaminated ground water have been predominantly associated with its risks to human health. 350,000 people have been provided with alternative sources of drinking water at Superfund sites alone, and as the percentage of the Nation's population that relies on ground water expands past 50 percent, the number of people at potential risk will increase. Concern is growing about the extent to which ground water is impacting ecosystems, particularly through ground water transfer of contaminants to sediments and to surface water, which can be significant in some watersheds during periods of low flow.

Due to the complex nature of the contaminants at many sites and the complex subsurface hydrogeology encountered at most sites, there are many uncertainties associated with the assessment and management of ground water contamination and the cost of these activities is high. These are summarized below.

For risk assessment, the major uncertainties are:

- transport and fate mechanisms, particularly in complex strata
- predicting human toxicity of complex mixtures
- predicting risk to ecosystems

For site characterization, major uncertainties are:

- delineating the location of ground water contaminants, particularly non-aqueous phase liquids (NAPLs)
- speciation of contaminants, particularly metals
- sampling and detecting contaminants at low concentrations
- achieving quick, low-cost ground water and NAPL characterization

For remediation, major uncertainties are:

- achieving cleanup goals of NAPLs and contaminated ground water
- assessing and optimizing long-term effectiveness of *in situ* ground water treatment and containment techniques
- achieving rapid, low cost cleanup

To address these uncertainties and associated high-priority research needs, 14 contaminated ground water research activities have been identified. The title and a description of the proposed research focus addressed by each activity are listed in Table 2-5. These activities were first ranked by a set of Science criteria and then a set of Science Plus criteria following a process described earlier in this chapter. These rankings are shown in Table 2-5 and the rationale for them is described in what follows.

Science Ranking

ORD has determined that the most significant problems to be addressed by contaminated ground water research are: 1) understanding the effectiveness and applicability of natural attenuation; and, 2) the characterization and remediation NAPLs -- a major *source* of ground water contamination. Assessment and remediation of ground water contaminated by dissolved pollutants is an important, but somewhat lower priority. These conclusions are based on several considerations. Natural attenuation (NA) has the potential for being a relatively inexpensive means of remediating sites. It appears, for example, that it is an effective technique for the remediation of fuel contamination under certain conditions. There is, however, very limited understanding on how to assess whether natural attenuation is working at a site. This includes locating the plume and determining the rate of contaminant disappearance. Proper site characterization and monitoring to show that NA is effective and protective may increase its costs substantially.

NAPL research is also a high priority. NAPLs act as a persistent source of ground water contamination, and the resultant loss of the ground water resource and threat to human health and the environment may last for tens of decades. Without the removal or control of these major sources, treatment of contaminated ground water must go on indefinitely. Research results that will enable locating and chemically characterizing NAPLs will aid in the development of new, cost-effective risk management options, as will continued development of innovative NAPL extraction and destruction options.

Research on the assessment and remediation of contaminated ground water remains important. Techniques for cleaning up many *sources* of ground water contamination do not now exist and therefore improved, cost-effective plume remediation or containment techniques continue to be needed to minimize risks from contaminated ground water. Similarly, improved techniques to characterize and assess the risks of ground water

contamination are needed to set realistic cleanup goals and reduce cleanup and monitoring costs.

Research on ecosystem impacts of ground water was ranked low because health concerns are still of highest priority. Also, the impacts of ground water on ecosystems are limited, being mainly through contamination of riparian zones (e.g., sediments and surface waters); since during low flow periods ground water can significantly contribute to base stream flow. Also, since many contaminated sites lie beside or near surface waters, direct runoff from the sites is believed to be of greater importance than transport through ground water. However, many uncertainties about these ecosystems impacts exist, and therefore research in this area needs to be done if adequate funds exist.

Science Plus Ranking

As can be seen from Table 2-5, the Science Plus ranking of research activities differs from the Science ranking for research activities ranked in the lower half of the list, but the changes in ranking are not large. First, containment research was elevated in ranking because it is of high priority to OSWER. Second, the ranking of the two demonstration/verification activities was increased 1 to 3 places reflecting ORD's recognition that Congress has indicated that these activities are a priority through its explicit authorization of the SITE Program, its mandate for ten SITE demonstrations and its guidance that SITE be fully funded in FY97. Also, the SITE program recently received a very favorable SAB review. Third, as a result of these three increases in ranking, mixtures toxicology human health effects research fell to a lower priority.

With the exception of these four changes the ranking of research activities changed little from Science to Science Plus. This reflects the fact that with one exception, all the Science Plus ranking factors were equally applicable to all research activities in this topic area. These factors were: 1) high priority for research across the risk paradigm in the CENR report and by the Program Office; and, 2) high Congressional priority (as reflected by the annual Superfund appropriation of about $1.5 billion [22 percent of the Agency's budget]) and high Administration priority (as reflected by the President's initiative to cleanup two-thirds of the Superfund sites by 2000, and by the tight, 8-10 year schedules for DOD and DOE site cleanups).

The remainder of this discussion of ground water research ranking describes in detail the relative Science Plus ranking of the fourteen research areas. This description reflects the application of both science and other factors (listed above) to determining the importance of each research activity.

The **Natural Attenuation** research activity was ranked high for reasons described above. This particular research activity is focused on remediation issues and is supported by subsurface characterization and field analytical methods research.

Human Dose-Response Models for Mixtures was ranked high because there are currently very large uncertainties about the health risks from complex mixtures of ground-water contaminants. The presence of multiple contaminants may result in enhanced toxicity (synergism), decreased toxicity (antagonism), or a simple summation of the toxicities of the individual contaminants (additivity). Current practice is to generally assume additivity which can result in either an under or over estimation of the actual risk. Research in this area will utilize *existing* scientific toxicologic studies and mechanistic data to develop dose-response models and toxicity values for common mixtures of contaminants. **Mixtures Toxicology** was ranked lower because hazard identification was judged less urgent a need than developing dose-response models or factors because existing studies of individual contaminants should first be used to develop dose-response models before initiating toxicologic studies of mixtures. Once dose-response models have been developed with the existing data base, then toxicologic studies would be initiated on actual mixtures and those results could then be compared to those predicted by earlier dose-response models developed using existing dose-response and mechanistic data for individual contaminants.

The **Subsurface Characterization** research activity was ranked high because of the inherent complexity of the subsurface and the contribution of the research activity to resolving both NA and NAPL characterization problems.

Environmental Fate and Transport Modeling is a high priority because it is a basic tool for integrating our understanding of the various natural and contaminant-induced processes that occur in an aquifer into a complete algorithm which approximately describes that subsurface environment. Ground water modeling allows us to understand how these various processes, along with remediation activities, impact contaminant fate and transport, including those for NA and NAPLs. Such an understanding is important scientifically, as well as to make site-specific assessment and cleanup decisions.

Abiotic Treatment was ranked high because a major part of its focus is on NAPLs remediation. In addition, it involves studying *in situ* abiotic treatment options such as permeable reactive barriers, which are being shown to be a more cost-effective option than pump-and-treat for major classes of contaminants in ground water, such as metals and chlorinated solvents.

Field and Screening Analytical Methods were ranked high because this area would develop improved methods to characterize and monitor sites for natural attenuation and

because of the need for quicker, less expensive characterization and monitoring methods. Methods from this research would also provide a more thorough characterization because more samples could be analyzed in the field and the results used immediately to more efficiently direct ongoing sampling or remediation activities.

Biotreatment and **Containment** research activities were ranked lower because they deal primarily with the control and remediation of contaminated ground water, a lower priority than NA and NAPLs cleanup. Biotreatment remains important to consider along with abiotic treatment because the two are likely to complement each other in terms of the contaminants they can address. Also, biotreatment may have application to residuals from NAPLs extraction. Under the Science ranking, containment was ranked lower than biotreatment because ORD believes that remediation of contaminants is at least as important as containment in terms of risk management, and because pump-and-treat can be used as a containment technique at many sites. The ranking for containment was increased because OSWER feels that it is an option of equal importance to treatment with significant implementation uncertainties. Containment research is particularly important for minimizing NAPL transport, for confining plumes to allow NA to occur, and for determining the long-term effectiveness of containment systems.

Ground Water Exposures Factors / Pathways was ranked in the middle because current research has been successful in identifying and quantifying key exposure factors such as drinking-water intake rates for various activities, but there are still significant uncertainties associated with estimates of contaminants from non-ingestion routes of exposure such as showering and use of appliances.

The two research activities dealing with **Demonstration / Verification of Innovative Technologies** were moved up in the Science Plus ranking because of the high priority allotted to them by Congress. While these two research activities do not develop new technologies, they are an important ORD activity for contaminated ground water (and soils) because they allow ORD to evaluate technologies developed outside the Agency and through these "independent" evaluations provide credible reports on the applicability, performance and cost of these technologies to a site managers and other decision makers. Evaluation of innovative ground water remediation technologies is particularly important because there are no effective technologies currently available. Evaluation of innovative ground water contamination characterization techniques is also important to help fill gaps where there is a lack of adequate techniques and to improve cost-effectiveness.

Research on **Mixtures Toxicology** was ranked lower because the need to develop information on interactions between mixture constituents was judged less urgent than the need to develop dose-response models for mixtures using existing databases.

Ecosystems Effects and **Ecological Risk Assessment Methods** were ranked lowest because while there are many uncertainties about assessing the effects of ground water on ecosystems, the impact is expected to be low compared to human health impacts. Therefore, research in these areas is ranked low compared to the need to characterize and clean up ground water contamination to protect human health.

Table 2-5. Focus and Ranking of Research Activities for Contaminated Sites - Ground Water

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Natural Attenuation (NA)	• Determine under what conditions NA is applicable. • Determine techniques for assessing site-specific applicability of NA.	1	1
Human Dose/Response Methods for Mixtures	• Develop biologically-based toxicity models. • Develop expert systems for determining likelihood of synergism antagonism or additivity of response.	2	2
Subsurface Characterization	• Develop surface based, noninvasive methods to characterize the structure and contaminant distributions in the subsurface.	3	3
Environmental Fate and Transport Modeling	• Determine processes affecting contaminant fate of transport, particularly in heterogeneous environments. • Develop improved models for representing site-specific ground water fate and transport, and effects of remediation.	4	4
Abiotic Treatment	• Develop more cost-effective techniques for NAPL remediation. • Develop more cost-effective techniques for ground water remediation.	5	5
Field and Screening Analytical Methods	• Develop field portable and screening analytical methods for rapid analysis of ground water. • Develop analytical methods to determine the status of and to monitor the rates of natural attenuation in ground water.	6	6

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Biotreatment	• Determine more cost-effective techniques for ground water remediation.	7	7
Containment	• Develop more cost-effective methods to contain NAPLs and contaminated ground water. • Develop methods for evaluating long-term effectiveness of containment systems.	10	8
Ground Water Exposure Factors/Pathways	• Determine contaminant intake rates from showering, bathing and use of household appliances (e.g., dishwashers). • Develop exposure models for vapors released indoors.	8	9
Demonstration/Verification of Innovative Ground Water Remediation Technologies	• Produce technically sound performance, cost and applicability data for full-scale innovative remediation technologies .	11	10
Demonstration/Verification of Field Monitoring Technologies	• Produce scientifically sound performance data for innovative ground water monitoring and characterization technologies.	13	10
Mixtures Toxicology	• Develop improved models of the synergistic/antagonistic effects of contaminant mixtures.	9	12
Ecosystem Effects	• Develop screening tests to determine the effects of contaminated ground water on ecosystems.	12	13

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Ecological Risk Assessment Methods	• Develop methods to determine to flux of ground water contaminants into sensitive ecosystems such as wetlands. • Develop ecotoxicity transfer/dilution factors between ground water and surface water. • Develop ground water ecotoxicity criteria and screening levels.	14	14

Ranking Research on Contaminated Sites - Soils/Vadose Zone

The complexity and heterogeneity of soil/vadose zone matrices present a large number of technical challenges to their assessment and remediation. There are numerous uncertainties associated with soil/vadose zone decisions and the cost of their remediation is still quite high (an average of $27M per Superfund site in 1993). Local risks to humans and ecosystems, high costs and uncertainty in decision making are all reasons for supporting contaminated soil/vadose zone research.

Specific scientific uncertainties are associated with each step of the site evaluation and remediation process. In the risk assessment process, major uncertainties are:

- magnitude of effects on human health and the ecosystem
- contributions of indirect pathways to receptor exposure
- availability of adsorbed contaminants and treatment residuals to human and ecological receptors
- intake of contaminants across multiple exposure routes: ingestion, dermal exposure, and inhalation

In the site characterization process, major uncertainties are:

- sampling of contaminants to determine their location and magnitude
- quantitative analysis of selected compounds
- design of site-specific sampling strategies
- physical characterization of soils and the vadose zone

In remediation, major uncertainties are:

- applicability of treatment techniques to different contaminants and soil matrices, particularly heterogeneous matrices
- cost of remediation techniques

To address these uncertainties and associated high-priority research needs, 13 research activities were identified. The title and a description of the research focus of each research activity are listed in Table 2-6. These activities were first ranked by a set of Science criteria and then a set of Science Plus criteria following a process described earlier in this chapter. These rankings are shown in Table 2-6 and the rationale for them is described in what follows.

Science Ranking

ORD determined that a combination of site characterization, risk assessment and remediation research is needed in this topic area, and that there are research activities in all three that are of high priority because they address important scientific and technical issues that can help to clarify the risks posed by contaminated sites to surrounding communities and reduce the high costs of site remediation. There are improvements needed in site risk assessments to reduce uncertainties in the

magnitude of human health effects, and there are limited tools to evaluate the risks which these sites pose to ecosystems. The high cost of site remediation (and the inability to effectively clean up some sites with available technologies) requires research on innovative technologies. And, improved site characterization contributes to both risk assessment and risk management, helping to more accurately define risks and define what needs to be remediated.

Science Plus Ranking

As can be seen from Table 2-6, the Science Plus ranking of research activities varies little from the Science ranking for contaminated soils/vadose zone, except that the two research activities on demonstration/verification of innovative technologies are ranked higher in the Science Plus ranking. This reflects the fact that with this one exception, all the Science Plus ranking factors were equally applicable to all research activities in this topic area. These factors included: 1) high priority for research across the risk paradigm in the CENR strategic plan and by the Program Office; and 2) high Congressional priority (as reflected by the annual Superfund appropriation of about $1.5 billion) and high Administration priority (as reflected by the President's initiative to cleanup two-thirds of the Superfund sites by 2000, and by the tight 8 -10 year schedules for DOD and DOE site cleanups).

The two demonstration/verification research activities were given a higher ranking under Science Plus because Congress has indicated the importance of such work by requiring that ORD conduct ten demonstrations per year as part of the SITE program.

The remainder of this subsection describes the rationale for the relative Science Plus ranking of the 13 research areas. This ranking reflects the application of both science and other factors to determining the importance of each research activity.

The **Estimating Human Exposure and Delivered Dose** and **Biotreatment** research activities were ranked highest, in part because both address the availability of contaminants in soils to impact receptors, particularly humans. Currently, it is assumed that all or most of an agent found in soils is biologically available, but this assumption is probably inaccurate most of the time. Improved estimation of the fraction of contaminants that are toxicologically available to humans or ecosystems could significantly reduce the estimates of risks at contaminated sites and reduce the cost of remediation by raising the level of the cleanup standard. The Estimating Human Exposure research activity would develop better models and factors for making these estimates for individual contaminants in the soil matrix. Research in this area would include developing models for dermal exposure, estimating soil intake rates for children and adults, and estimating bioavailability of contaminants. In the long term the Biotreatment research activity would evaluate the effectiveness of different types of biotreatment processes in different soil media based on these models and factors.

The Estimating Human Exposure research activity was also ranked high because its goal is to reduce other uncertainties associated with risk characterization. These include increasing the certainty of multipathway analysis, developing statistical distributions for exposure factors, and addressing specific issues related to soil risk, such as intake rates for children and adults.

The Biotreatment research activity was also ranked high because it would address natural attenuation of contaminants in soils (and landfills). Natural attenuation in soils has the potential for being a relatively low-cost means of site remediation, if its selection is justified and its progress is monitored to insure that there are no significant environmental risks. In addition, the Biotreatment research activity develops enhanced biotreatment processes for soils, vadose zones and landfills. These all have the potential to significantly reduce remediation costs, particularly *in situ* processes.

Estimating Soil Intake and Dose by Wildlife Species was ranked in the upper half because, while human impacts have been the principal risk addressed in setting cleanup goals, ecological risks are becoming more significant as drivers of cleanup levels at many contaminated sites. In most cases, soils are believed to have a more significant ecological risk at contaminated sites than do contaminated ground waters, due to the greater variety of wildlife that can come in direct contact with contaminated soils and/or feed on species residing in these soils. There are numerous uncertainties about the extent to which soil contaminants impact ecosystems and therefore ecosystems may not be adequately protected.

The two research activities **Field Sampling Methods** and **Field and Screening Analytical Methods** were both ranked near the top because: a) uncertainty associated with site characterization is often high, thereby leading to uncertain risk assessment or high remediation costs, and b) there are significant savings in time and money to be gained by conducting analyses in the field.

Ecological Screening Tests to Measure Effectiveness of Treatment was ranked near the middle because while it addresses the important topic of toxicological availability of residual contaminants to ecosystem receptors, it deals only with bioavailability issues and therefore is a more narrowly focused research area than Estimating Human Exposure or Wildlife Species research.

The **Containment** research area was ranked in the middle because its use is increasing because of its relatively low cost, yet there are still uncertainties about the long- term effectiveness of these systems and the most effective ways to install them. Also, there is the potential to reduce costs further by utilizing new materials for containment.

The research activity **Sampling Design** was ranked in the middle because improved designs can have a significant impact on reducing costs of cleanup by more accurately identifying what volumes of soils need to be remediated and what and where the sources of the risks are.

The two research activities dealing with **Demonstration / Verification of Innovative Technologies** were moved up in the Science Plus ranking because of the high priority allotted to them by Congress. While these two research activities do not develop new technologies, they are an important ORD activity for contaminated soils (and ground water) because they allow ORD to evaluate processes developed outside the Agency and through these "independent" evaluations provide credible reports on the applicability, performance and cost of these processes to site managers and other decision makers.

The **Abiotic Treatment** research area was ranked below Containment, Biotreatment and Demonstration/Verification of Innovative Remediation Technologies because it was judged to have somewhat less potential to impact cleanup costs or to achieve significantly lower remediation levels. There are, however, important areas where abiotic treatment, either alone or as part of a multi-facetted management option, is need for cost effective site clean up.

The two remaining research activities: **Mixtures Toxicology** and **Oil Spills** are all important areas for contaminated soil research, but are of less importance than the other research activities. Oil spills was ranked relatively low because its primary impact is to ecological systems. Research on Mixtures Toxicology of soil contaminants was ranked lower because due to the sequence in which activities should be conducted to maximize research yield. For example, knowledge of the bioavailability of soil contaminants assists in predictions of the toxicological impact of mixtures.

Table 2-6. Focus and Ranking of Research Activities for Contaminated Sites - Soils / Vadose Zone

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Estimating Human Exposure and Delivered Dose	• Estimating soil intake rates for children and adults. • Evaluating the bioavailability of contaminants in various soil matrices. • Develop and validate biokinetic dose-response models for lead and other heavy metals. • Deriving dermal absorption factors for common soil contaminants. • Developing biotransfer and bioaccumulation factors for contaminants to facilitate estimates of exposure via the food chain. • Developing statistical distributions for exposure factors to facilitate use of probabalistic techniques to evaluate variability and uncertainty (e.g., Monte Carlo methods).	1	1
Biotreatment	• Determine under what conditions biotreatment processes can reach risk-based cleanup levels. • Develop less expensive cleanup processes for frequently found hard-to treat contaminants (e.g., TCE, PAHs, PCBs). • Develop inexpensive permanent cleanup options for land fills • Determine when natural attenuation is an appropriate remediation option for soils and landfills.	1	2

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Estimating Soil Intake and Dose for Wildlife Species	• Developing critical ecological exposure factors such as: species-specific soil intake rates, uptake factors from soils to plants to herbivores, species-specific dietary factors uptake factors from herbivores to carnivores, and data on migratory and range patterns. • Developing a wildlife contaminant exposure model that should be useful for constructing and evaluating site-specific scenarios. This model would allow calculations of intake via the food web the analysis of multiple exposure pathways and species and would also include a probabalistic component to evaluate variability and uncertainty.	4	3
Field Sampling Methods	• Develop sampling methods that better preserve the integrity of contaminants in soil (e.g., volatile organic compounds). • Develop sampling approaches to better ensure that a sample is "representative" of the area surrounding the sample location.	3	4
Field and Screening Analytical Methods	• Develop field-portable methods for rapid *in situ* determination of contaminants in soils. • Develop analytical methods to determine the status and rates of natural attenuation in soils.	4	5
Containment	• Develops methods for evaluating the long term effectiveness of containment systems. • Develop more cost-effective containment systems.	6	6
Ecological Screening Tests to Measure Effectiveness of Treatment	• Develop inexpensive methods to screen for significant risks from treatment residuals. • Develop inexpensive methods to determine cleanup goals.	6	6

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Sampling Design	• Develop new statistical designs for sampling/characterizing contaminated soils at waste sites (e.g., multivariate, 3-D technologies).	8	8
Demonstration/Verification of Innovative Remediation Techniques	• Produce technically sound performance, cost and applicability data for full-scale innovative remediation techniques.	12	9
Demonstration/Verification of Innovative Monitoring Technology	• Produce technically sound performance data for innovative soil monitoring and characterization technologies.	12	9
Abiotic Treatment	• Develop less expensive cleanup processes for hard-to-treat contaminants and matrices.	9	11
Mixtures Toxicology	• Develop improved models of the synergistic/antagonistic effects of common soil contaminant mixtures.	10	12
Oil Spills	• Develop more effective ways to remediate spills in an environmentally safe manner.	10	13

Ranking Research on Active Waste Management Facilities

The current regulatory approach to the management of hazardous wastes is considered extremely burdensome and costly to the US economy. In addition, the regulations are considered overly conservative and not well-founded on risk. As a result, the Administration is proposing regulatory reforms to provide administrative and economic relief by developing a multimedia, multipathway risk-based approach that is expected to exclude many wastes and waste streams from regulatory control under Subtitle C of RCRA (Hazardous Waste Identification Rule [HWIR]). For this new regulatory approach to be successful, significant new research is needed to provide the science underpinnings. In addition, acceptable disposal of hazardous wastes is specified by Land Disposal Restriction (LDR) rules. As part of these rules, Best Demonstrated Available Treatment (BDAT) technologies are specified that must be used to treat the waste prior to disposal. BDAT technologies were identified for each hazardous waste stream in the late 1980s and early 1990s and were based on the most effective treatment technologies that were commercially available at the time. It was recognized that there were some hard-to-treat wastes for which available technologies were either not sufficiently effective, or were very expensive, and that ongoing efforts would be needed to upgrade the BDAT technologies for a limited number of hazardous waste streams.

Major uncertainties are associated with several elements of the risk paradigm. Of the 400 waste constituents that require the development of “exit levels” under the proposed HWIR, 220 are without health-based levels (even fewer for ecologically-based levels). These values need to be determined or estimated. In addition, approximately 210 of the constituents are without adequate analytical methods i.e., current methods cannot measure the constituents at the proposed exit levels. Current multimedia modeling approach is constructed on a “most critical pathway” basis rather than on a mass balance basis. Components of some of the models are probabilistic and well developed (e.g., ground water) and others are poorly developed and deterministic or not developed at all. There is no system or computer backbone that will allow/facilitate scientifically sound integration/communication between existing or planned components (models and data bases). Existing data bases (toxicity and environmental fate) are out of date and need to be updated with existing literature and/or new original data. Methodology / approaches to conduct assessments on mixtures or to account for cumulative effects are nearly non-existent. Sound approaches (modeling, sampling design, analysis) for determining specific waste constituent compliance with proposed exit levels do not exist or, at best, have not been validated.

Uncertainties still exist in the treatment of some hazardous waste streams. There still remain a number of hard-to-treat waste streams, such as streams containing mercury. As a result, it is not always possible, using current treatment technologies, to obtain the desired cleanup levels. In addition, there have been advances in existing,

inexpensive treatment technologies (e.g., solidification/stabilization) which may make them more broadly applicable than previously, thus reducing costs of hazardous waste management.

Also, there is a need to reduce the volume of solid wastes that need requiring disposal and this is not being done as quickly as it might, partially because of the uncertainty about the applicability of innovative recycling processes. This uncertainty may be reduced by improving the availability of technically sound information on innovative recycling techniques by having independent evaluations done on them cooperatively by government and private sectors.

To address these uncertainties and associated high priority research needs, six research activities have been identified. The title and a brief description of the research needs addressed by each research activity are listed in Table 2-7. These activities were first ranked by a set of Science criteria and then a set of Science Plus criteria following a process described earlier in this chapter. These rankings are shown in Table 2-7 and the rationale for them is described in what follows.

Science Ranking
ORD has determined that a combination of environmental fate, exposure modeling, risk assessment, and waste management research is needed in this topic area and that all four research areas are of high priority because each addresses important scientific and technical issues that can help determine or reduce the risks posed by active waste management facilities and hazardous waste generators.

Science Plus Ranking
As can be seen from Table 2-7, the Science Plus ranking of research activities is identical to the Science ranking except that the activity, “Chemical Toxicity Testing for Human and Ecological Effects” moved to the bottom of the list. This reflects that with one exception, all the Science Plus ranking factors had little impact in this topic area. These factors included: 1) high-priority across the risk paradigm in the CENR Strategic Plan and by the Program Office (OSW), 2) HWIR as a high-priority effort under the Administrations regulatory reform efforts, 3) the identification of waste research as “an area of high importance” in the ORD Strategic Plan, and 4) Agency Science Advisory Board (SAB) and ORD recommendations for research resulting from their review of OSW’s proposed Hazardous Waste Identification Rule (HWIR). ORD considers the “Chemical Toxicity Testing for Human and Ecological Effects” research need to be of lower priority since it is essentially routine testing (application of standard protocols to develop toxicity data), expensive, and a low-priority use of ORD's limited staff or facilities.

The remainder of this section describes the rationale for the Science Plus relative ranking of the six research areas. This ranking reflects the application of science and other factors to determine the relative importance of each research activity.

The first four research areas (**Multimedia, Multipathway Exposure Modeling; Environmental Fate and Transport, Physical Estimation; Developing Provisional Toxicity Values for Contaminants;** and **Waste Characterization and Sampling**) are all linked, in that they are responsive to the research needs identified by recent ORD and SAB reviews of the proposed HWIR. Research in all four areas is needed if a scientifically sound HWIR approach is to be developed. Current exposure and risk models lack the ability to produce true multimedia, multipathway analyses. Major improvements are needed to ensure various models are compatible from the perspectives of computational, pathway, environmental scale, time scale, error propagation, mass conservation/balance, etc.,. Significant uncertainty still remains in the fate, transformation, and transport of many of the waste contaminants regulated under RCRA. These uncertainties include metal and organic compound speciation and the effects/rates of reductive and biological fate processes. As indicated above, provisional toxicity values for human and ecological receptors are needed for at least 220 of the 400 waste constituents. Until test-based toxicity values become available these values will have to be estimated from the literature, from structure activity relationships or from physical/chemical properties of the constituent. Much uncertainty remains in these current estimation methods, especially related to mixtures, bioavailability, and pharmacokinetics. As is the case for toxicity values, analytical methods are inadequate (as a result of poor sensitivity or specificity) or nonexistent for 210 of the 400 constituents. For wastes and waste constituents to “exit” regulatory control under RCRA, they must be present at concentrations *less than* the proposed “exit level” values developed through the multimedia, multipathway risk assessment approach proposed in HWIR. Great uncertainty exists, however, in how this is determined. For example, how many samples, what sampling methods, over what spatial and temporal scales are needed for each type of waste or waste disposal facility to make this determination? OSWER has estimated that hundreds of millions of dollars per year can be saved as a result of this regulatory approach, but the above research is needed to ensure the science is available to support a creditable HWIR. (OSW, 1995c)

The **Waste Management** research area ranks fifth out of six areas. It is relatively less-important since it is a much more mature research area for ORD and significant resources have been committed to this area in the past. Most RCRA wastes and waste streams have established BDATs, however, there are still a number of “hard to treat” wastes where research could provide new or less-expensive technological solutions.

Chemical Toxicity Testing for Human and Ecological Endpoints ranks sixth out of six because it is the routine application of standard toxicity testing protocols and is very expensive, thus, not a high-priority use of limited research resources.

Table 2-7. Focus and Ranking of Research Activities for Active Waste Management Facilities

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Multimedia, Multipathway Exposure Modeling	• Develop true multimedia, multipathway exposure and risk models that support HWIR.	1	1
Developing Provisional Toxicity Values for Contaminants	• Review animal toxicologic studies, human epidemiologic studies, structure activity relationships, and then conduct dose-response assessments to derive Reference Doses, Reference Concentrations and/or cancer slope factors.	3	2
Environmental Fate and Transport; Physical Estimation	• Provide the science and environmental data needed to understand the fate, transport and transformation of RCRA constituents.	2	3
Waste Characterization and Sampling	• Develop the sampling methods, techniques and designs necessary to determine compliance with proposed RCRA exit level values. • Develop analytical methods with the necessary specificity and sensitivity to support exit level determination and compliance monitoring.	5	4
Waste Management	• Develop more cost-effective treatment options for hard-to-treat wastes. • Determine the applicability of innovative treatment options to hazardous wastes.	6	5
Chemical Toxicity Testing for Human and Ecological Endpoints	• Perform toxicity testing for high priority contaminants constituents of hazardous waste streams.	4	6

Ranking Research on Emission from Waste Combustion Facilities

Currently, there are 307 municipal waste combustion facilities with a capacity of 104,000 tons per day. About 30 million people in 35 states and 900 communities are served by municipal waste combustion facilities. This accounts for approximately 16 percent of the waste generated annually. These facilities are known to emit toxic contaminants such as dioxin, furans, cadmium, lead, and mercury. In addition to large municipal waste combustion facilities, there are thousands of small incinerators such as those used to dispose of medical wastes. Recent studies indicate that medical waste incinerators are likely a major source of mercury emissions. There are also over 300 facilities burning hazardous wastes. All of these units are burning complex mixtures of toxic contaminants, often in high concentrations, and therefore can contribute significant emissions on a site-specific basis if improperly designed or operated.

The risks associated with combustion facilities are potentially very high because (1) the number of combustion facilities is high, (2) the facilities have the potential to emit very toxic contaminants such as dioxin, furans, mercury, lead, and cadmium, (3) these emissions become dispersed over large geographic areas that often have large populations or produce important food products (crops, animal, and dairy products), and (4) exposure occurs over several pathways and routes. These risks are also perceived by the public as very high as evidenced by community protests at facilities such as Waste Technologies Incorporated (WTI) in East Liverpool, Ohio, and at many Superfund sites such as New Bedford Harbor, Massachusetts, and Bloomington, Indiana.

The risks associated with combustion facilities are also highly uncertain and cut across the risk assessment paradigm. Areas of major uncertainty in exposure assessment include:

- What contaminants are being? What additional contaminants are formed as the emissions disperse and are transformed in the environment?

- What is the fate and transport of the contaminants? Where do they go and who might be exposed? What is the geographical scale of exposure? Current studies indicate that airborne contaminants are extremely mobile and can affect regional receptors.

- How much contamination are people and ecological receptors exposed to? Through what exposure pathways? How much contamination eventually makes its way into our food? And how much of the contamination found in our food is bioavailable to cause a toxic response in human receptors?

- How effective and accurate are current monitoring technologies?

Areas of major uncertainty in hazard assessment include:

- How toxic to *humans* are the contaminants that are being released? What doses of dioxin, furans, mercury, lead, cadmium and other contaminants are safe for human receptors?

- How harmful to *ecological receptors* are the contaminants that are being released? What amounts of dioxin, furans, mercury, lead, cadmium and other stressors are harmful?

Areas of major uncertainty in risk characterization include:

- Which contaminants being emitted present the greatest risk to human health and the environment and, thus, should be the focus of control efforts?

- What is the risk of cumulative continuous exposure? Combustion facilities are normally evaluated and regulated based on their *individual* emissions, exposure, and risk to surrounding receptors. However, receptors to those emissions are exposed from multiple sources of contaminants. Therefore, the cumulative impact of continuous emissions from multiple combustion facilities and other sources of contaminants is not known.

The areas of greatest uncertainty in risk management are:

- How can emission levels of contaminants be most cost-effectively reduced?

- What are the combustion processes that lead to containment formation?

- Are process design/operation changes appropriate, or should add-on controls be used? What are the cheapest ways to minimize emissions from small combustors? How can the control of multiple emissions be most cost-effectively accomplished?

To address these uncertainties and associated high priority research needs, six research areas were identified: (1) exposure characterization and modeling, (2) continuous emission monitoring, (3) evaluation of the movement of metals in the food chain, (4) indirect pathway risk assessment methods, (5) dose-response assessments of key contaminants, and (6) emissions prevention and control.

The title and a description of the research needs addressed by each research activity are listed in Table 2-8. ORD first ranked these research areas relative to each other

based on the potential for the research to either reduce risk; reduce uncertainties in risk estimation, site characterization or risk assessment; or reduce cleanup costs. The third column of Table 2-8 lists the research activities in order of decreasing priority based on this Science ranking. The fourth column Table 2-8 lists the ranking of research activities in terms of Science Plus, reflecting revised priorities based on Congressional mandates, Program Office and Regional priorities, and other important considerations that are more of a managerial nature than solely scientific-based. This Science Plus ranking was derived by adjusting the Science ranking based on these additional factors.

As can be seen from Table 2-8, the Science Plus ranking of research activities is identical to the Science ranking for waste combustion facilities. This reflects the fact that all the Science Plus ranking factors were equally applicable to all research activities in this topic area. These factors included: 1) high priority for research across the risk paradigm in the CENR report, 2) high Administration priority as reflected by the Administrator's Combustion Strategy which requires that all hazardous waste combustion facilities be evaluated for health and ecological impact using the indirect exposure methodology, 3) high priority by the Program (Office of Solid Waste) and Regional offices as evidenced by their commitment to establish with their own funds a Technical Support Center to evaluate indirect exposures, and 4) listing of waste research as "an area of high importance" in the ORD strategic plan.

As can also be seen from Table 2-8, consideration of the Science Plus criteria did not impact any of the rankings *within* the Combustion Facility research topic. Applying the Science Plus criteria resulted only in some minor changes in the ordinals when combustion facility research areas were compared to the other three hazardous waste topic areas. The combustion research areas dropped to slightly lower ranks due to several factors. First, issues relating to combustion were judged by ORD as not as high a priority to the program offices as contaminated ground water or contaminated soil. Secondly, Congressionally authorized programs which received relatively lower science rankings (e.g., various SITE demonstration programs) were bumped upward in their science plus rankings.

As shown in Table 2-8, the Waste Research Coordination Team (RCT) judged that the highest priority areas within the waste combustion facility topic area were emission prevention and control, and exposure characterization/modeling. ***Emission Prevention and Control*** involves the characterization of waste combustion systems and their emissions along with the development and evaluation of techniques to prevent emissions formation and/or control their release. This area addresses incinerators and industrial systems burning wastes. It studies the reduction of emissions by system design and operation changes, as well as through the use of add-on controls. This area was judged as the highest priority because of the high potential

for risk reduction and cost savings that could be achieved with reduced emissions from the waste combustion facilities. ***Indirect Exposure Characterization/Modeling*** involves developing improved fate, transport, and transformation models of contaminants that are emitted from waste combustion facilities. Currently available models lack the robustness and resolution to provide adequate fate and transport data needed to accurately estimate exposure and risk. Potential avenues of research include: developing improved/validated complex terrain models for combustion sources, vapor-particle partitioning of semi-volatile organics (chlorinated dioxins and PAHs) under ambient conditions, air deposition of semi-volatile organics (chlorinated dioxins, PCBs, higher MW chlorinated benzenes / phenols, PAHs, and high molecular weight phthalates), vapor transport to surfaces - wet and dry deposition, surface vapor uptake in plants and animals, mathematical models, parameter characterization, and validation of models for dry gas deposition and air dispersion, and methods for particle size distribution for input to air dispersion models. This area was judged as the highest priority because of the very large uncertainties associated with the fate, transport, and transformation of emissions from waste combustion facilities.

Research on ***Indirect Pathway Risk Assessment Methods*** is needed to develop, validate, and refine a methodology that estimates exposures from combustion facilities via indirect (non-inhalation) exposure pathways. The indirect exposure methodology (IEM) is a multimedia and multi-pathway model which was developed for application to numerous emitted pollutants being released from stationary combustion sources. The methodology was developed to provide a set of procedures for the estimation of exposures resulting from emitted pollutants that have been transferred from the atmosphere to environmental media and biota. In addition, indirect exposures may result from uptake and transfer of an atmospheric pollutant through the terrestrial or aquatic food. Tasks in this research area include refining and validating the algorithm , developing guidance manuals on how to properly select input parameters, and developing an expert system software package. Research in this area was judged to be a high priority because recent risk assessments of waste combustion facilities indicate that the greatest risks appear to be those caused by these indirect exposure pathways. Typically, the risks resulting from indirect exposure pathways are an order of magnitude higher than those from the direct inhalation of emissions.

Conducting ***Dose-Response Assessments of Key Contaminants Released*** was also judged to be a high priority. The purpose of this research area is to develop updated dose-response risk assessments for contaminants that present the greatest risk from combustion facilities. As more scientific data becomes available in the form of animal toxicological studies, human epidemiological studies, and mechanistic toxicodynamic models, current toxicity values (e.g., reference doses, reference concentrations, and cancer slope factors) will need to be updated to provide a more accurate estimate of risks. Because there is a linear relationship between the toxicity values and risk, any

change in the toxicity value will translate into the same change in estimated risk (e.g., if the toxicity of the contaminant is determined to be three times as potent, then the risk will also be tripled). Currently, the “risk drivers” are mercury, dioxin, furans, cadmium, and lead. Because there are many ongoing epidemiologic and toxicologic studies of these contaminants, the Waste RCT judged that it was very important that the results from these emerging studies be evaluated and that current toxicity values be updated if necessary so that the risks from waste combustion facilities can be accurately estimated.

Research on ***Continuous Emissions Monitoring Methods*** is another important research area. Acceptance of incineration as a viable treatment option for hazardous waste has been significantly hindered by our inability to provide assurance on a continuous basis that we know how well the combustion units are performing and whether there are any unexpected emissions. Efficient, reliable, cost-effective continuous emission monitors (CEMs) are needed. Emphasis in this research area would be on toxic metals (lead, mercury, cadmium), dioxins, furans and other semi-volatile organics. Simple, inexpensive methods are especially needed for monitoring the thousands of small incinerators (e.g., medical waste incinerators) around the country. While this research area is very important in providing assurance to the public about the reliability of operations and uncertainties associated with incinerator emissions, ORD judged this area to be less critical than the previously described research areas which should provide more reduction of uncertainty in our estimates of exposure and risk.

The purpose of research studying the ***Movement of Bioaccumulative Chemicals in Food Webs*** is to determine the ecological effects of emissions from combustion facilities by studying their uptake and transfer through terrestrial and aquatic food webs. Research would include the identification of indicator species and studies of species-specific exposure rates. Research would also include the study of contaminant bioavailability in combustor residues, including those from thermal treatment units. While this is an important area of research, ORD judged it to be a relatively lower priority because many of the principal contaminants of concern such as mercury and cadmium, have already been widely studied or are currently being studied by other programs. Any research would be targeted toward issues specific to waste combustion, such as bioavailability of specific forms of contaminants being emitted by waste combustion.

Table 2-8. Focus and Ranking of Research Activities for Emissions from Waste Combustion Facilities

Research Activity Title	Potential Research Focus	"Science" Ranking	"Science Plus" Ranking
Emission Prevention and Control	• Develop a better understanding of the combustion processes that lead to emissions formation. • Characterize toxic emissions from industrial hazardous waste combustion units. • Determine the most cost-effective means of controlling emissions from hazardous waste combustion units, especially industrial units and small incinerators.	1	1
Indirect Exposure Characterization/Modeling	• Determine the fate and transport of emission contaminants. • Develop models that identify and predict the formation of secondary contaminants from primary emissions.	1	1
Indirect Pathway Risk Assessment Methods	• Test and validate indirect exposure methodology (IEM) using site-specific data. • Develop and validate contaminant biotransfer and uptake factors. • Develop guidance manuals and software program to apply IEM procedures.	3	3
Continuous Emissions Monitoring Methods	• Develop improved instruments that measure (on a “real time” basis) what contaminants are being released to the environment.	5	4
Dose-Response of Key Contaminants	• Complete the risk assessment of mercury. • Develop toxicity values (Reference Doses, Reference Concentration, Cancer Slope Factors) for critical contaminants.	4	5
Studies of the Movement of Bioaccumulative Chemicals in Food Webs	• Determine ecological effects of metal emissions. • Study the movement of mercury in aquatic environments. • Determine bioavailability of metals.	6	6

Technical Support and Assistance

Technical support and assistance has always been a very high priority to OSWER and the Regions. ORD has historically provided it and views it as a significant part of its total research program. Essentially all of ORD's technical staff members provide some degree of technical support as part of their activities, and over one-third of those involved in the Superfund program provide technical support as their primary job. Technical support is important to ORD because it gives ORD researchers an opportunity to directly apply their research and provide opportunities to evaluate their new technologies under realistic site conditions. It is beneficial to the Program Offices and the Regions because it provides them access to the latest science and innovative technologies. As a result, ORD has identified technical support as one of the five areas covered under this research plan. Its associated support activities were not ranked as part of this process. These are not research issues or problems and the level and nature of this support is negotiated directly with the Program Offices.

For the purposes of planning, most of ORD's waste-related technical support comes under the following categories:

- Exposure Assessment Technical Support
- Risk Assessment Technical Support
- Remediation Technical Support
- Monitoring Technical Support

Most of the technical support is for contaminated site problems and these four categories reflect the areas where there are many uncertainties in contaminated site assessment and cleanup. A formal ORD program exists for providing support to OSWER and the Regions in these areas. In addition, more *ad hoc* technical support is being provided on some hazardous waste management issues, and ORD and OSWER are establishing an incineration risk assessment center.

Details on these technical support activities are provided in Appendix H.

Chapter 3
CONCLUSIONS AND ISSUES

Based on our analysis of research needs, and the subsequent ranking of research topics described in Chapter 2, ORD has identified several conclusions, as well as issues that may require further attention.

Conclusions

1. There is a large and diverse set of waste research needs that span the spectrum of the risk paradigm. As a result, well integrated research programs are needed for each research topic area which have the goal of improving our assessment, characterization and risk management capabilities. Because there are insufficient resources available to meet all these research needs, the process of ranking research topics and activities is critical.

The large volumes of solid and hazardous wastes generated in the United States pose a number of environmental problems which the US EPA is responsible for minimizing. Given the variety of waste types and of past waste management practices, it is not surprising that there are also a variety of technical and scientific issues which need to be addressed. The CENR report identified broad risk assessment and risk management research needs for waste-related environmental problems, and OSWER and the Regions identified related, but more focused needs that support their regulatory programs. Well integrated research programs which involve improved assessment, characterization and risk management are needed to address the most pressing waste research needs.

2. *Five high-priority research topic areas and associated research activities were identified: (Contaminated Sites - Ground Water, Contaminated Sites - Soils/Vadose Zone, Active Waste Management Facilities, Emissions from Waste Combustion Facilities, and Technical Support.)*

- Contaminated Sites - Ground Water.
  The NRC has estimated that 300,000 to 400,000 sites have contaminated ground water most from UST's, but, historically, about 80 percent of the NPL sites have contaminated ground water. The subsurface is also the most complex and costly media to characterize, model, assess, and remediate and there are still numerous scientific uncertainties associated with each of these topics. Congress appropriates approximately $1.2 billion annually to cleanup the NPL sites and the Waste Research Program has demonstrated repeatedly the ability of its research to significantly reduce these costs.

The focus of the research activities (Table 3-1) is on the issues of: improved risk assessment, characterization and remediation of non-aqueous phase liquids (NAPLs), the application and management of natural and accelerated process for subsurface remediation, and the demonstration and verification of innovative characterization and remediation technologies.

The activities shown in Table 3-1 for contaminated sites - ground water are currently funded in the base research program except for mixture toxicology and containment of ground water.

- Contaminated Sites - Soils/Vadose Zone.
  The complexity and heterogeneity of soil / vadose zone matrices presents many challenges to their characterization, assessment, and remediation. The cost of their remediation is still quite high, averaging approximately $27 million per site.

  The focus of research activities (Table 3-1) is on the issues of improved exposure and risk assessment of soils, the application and management of natural and accelerated process for remediation, and the demonstration and verification of innovative characterization and remediation technologies.

  The activities shown in Table 3-1 for contaminated sites - soils / vadose zone are currently funded in the base research program except for mixture toxicology and estimating soil intake and dose for wildlife species.

- Active Waste Management Facilities.
  Currently, hazardous waste regulations are considered burdensome and costly to the US economy. A proposal to provide administrative and economic relief by developing a multimedia, multipathway risk-based approach to exclude waste and waste streams has been made (Proposed Hazardous Waste Identification Rule). However, for this rule to succeed, significant new science, models and data are required. Also, OSWER has identified a number of waste control/ treatment issues for waste and waste streams that are hard to treat or where current technological solutions are too costly or do not meet current treatment standards.

  The focus of the research activities proposed for this research topic area is on the science needs related to HWIR especially in multimedia, multipathway modeling and the development or estimation of toxicity values.

  The activities shown in Table 3-1 for active waste management facilities are currently funded in the base research program except for the development of provisional toxicity values and waste management.

- Emission from Waste Combustion Facilities.
  Waste combustion facilities are know to emit toxic contaminants such as dioxins, furans, cadmium, lead, and mercury. In addition to large municipal waste combustion facilities, there are thousands of small incinerators such as those used to dispose of medical waste which are suspected of being a major source of mercury emissions. Public acceptance of incineration as a viable disposal technology is very low because of our inability to answer questions related to emission sources, emissions monitoring, indirect exposure pathways, and economical control and monitoring of small incinerators.

  The focus of research in this topic area is on the control and monitoring of emissions, emissions fate process and transport modeling, and indirect exposure and risk assessment methods and models.

  This entire research topic area is not currently funded in the base waste research program.

- Technical Support
  Site-specific technical support has been identified as the number one priority for OSWER and the Regions. Application of the latest science to the assessment, characterization and remediation of contaminated sites benefits both the client offices and ORD. As a result, sites are usually more effectively and efficiently cleaned up and ORD has actual field opportunities to apply and evaluate its latest methods, models, and technologies.

  Site-specific technical support and other support is provided in the areas of exposure modeling, risk assessment, measurement and monitoring, and remediation. In addition, technology transfer activities and technical support to the Program Office are provided.

  The program is currently jointly funded by ORD and the Program Offices and the Regions. ORD provides the scientist and engineers (approximately one-third of the ORD Superfund staff) salaries and facilities, while the Program Offices and Regions provide the extramural contract funds.

3. *While there is much uncertainty, debate, and controversy about the health and ecological risks posed by waste sites, there is consensus that the economic impact of current waste management and cleanup practices is staggering*. *Within this context, waste research should be viewed as a relatively small and valuable investment to save future expenditures.*

Waste management and remediation costs have been estimated to run as high as $750 billion (Russell et al. 1989). In contrast, ORD's research budget for FY 97 was less than $50 million. This research, however, has yielded significant savings. For example, at a mining site in EPA Region 8, a $50,000 bioavailability study reduced cleanup costs from $8 million to $4 million (Weiss, 1997). Similarly, use of a phased characterization / sampling and analysis design at a dioxin contaminated soil site resulted in an overall savings of approximately $6.0 million (Ryti, 1992, and Ryti, 1993). As another example, a survey of 17 sites showed that where innovative technologies of the type tested in the SITE program were used instead of conventional technologies, on average a savings of $21 million dollars per site was achieved. Clearly, there have been significant reductions in remediation costs resulting from research, and it is expected that future research will yield similar benefits.

4. *Because of the multi-disciplined nature of waste-related research, there are many organizations (across government, industry, and academia) actively involved in sponsoring research activities. In order to maximize efficiency of effort and avoid duplication, special efforts need to be made to coordinate and leverage these research programs and activities.*

5. ORD's current research program emphasizes risk management research. There is a need to increase the relative amount of risk assessment research in this program. About 80 percent of ORD's current waste research program is invested in risk management and monitoring, while only the remaining 20 percent is invested in risk assessment research. This is due to several factors. First, within ORD, the waste research program is the only place where characterization and remediation research specific to hazardous waste and Superfund sites is conducted. In contrast, a number of other ORD research programs (Human Health Protection, Ecological Research, etc.) have research efforts on topics related to generic risk assessment that benefit the waste programs. Additionally, Congress has required that ORD conduct ten technology demonstrations per year as part of the Superfund Innovative Technology Evaluation (SITE) program. These activities have consumed a significant portion of ORD's Superfund research resources. Finally, both the National Institute of Environmental Sciences (NIEHS) and the Agency for Toxic Substances and Disease Registry (ATSDR) have Congressionally mandated Superfund research programs to conduct basic research and develop toxicological profiles. While these efforts do not necessarily have a direct relationship to risk assessments at sites, they are helpful to the Superfund program.

There are several areas where risk assessment issues need to be addressed, either as part of the ORD waste research program, or by other research programs inside ORD or elsewhere. The research activities identified in Table 3-1 are those which should be conducted in whole or in part in the ORD waste research program. Both the risk

assessment research activities (left three columns) and the risk management research activities (right three columns) address high-priority research needs. This research strategy provides guidance on deciding the relative emphasis that should be placed on risk management and assessment research from FY97 to FY00.

Issues

1. *The lack of risk characterization research.* The CENR report identified risk characterization as a commonly overlooked, yet very important, research priority. As shown in Table 2-3, ORD does not have any research activities under this component of the risk assessment paradigm. Should ORD conduct additional research in this area? If yes, should it be part of the Waste Research Plan or is it more appropriate as part of another research plan such as the Research Plan for Human Health Risk Assessment?

2. *Future Waste Strategy Development.* This waste strategy and its associated research plans present the first comprehensive waste research planning done by ORD. The planning will not stop with publication of this document. The authors plan to coordinate ORD discussions which will lead to a more integrated set of research activities within each research plan, considering a contaminate-specific research focus as a means to insure an effective program. Thus, most of the appendices to this strategy will be updated in the next one to two years, and possibly released as separate documents. The research strategy itself will be revisited within two to three years to provide guidance beyond FY00.

3. *Funding Strategies*. As is clear from the conclusions presented above, the number and diversity of research needs far exceeds ORD's ability to meet all of them. We have identified a set of research activities through which we believe we can make significant scientific contributions and that are responsive to many of the high priority needs. However, some of these activities are not currently funded in our base research program (FY97). These unfunded research activities are identified in **bold** in Table 3-1. Strategically, we will use four approaches to identify funds for these unfunded priorities. They are:

- Annual Reallocation of Funds -- Annually, for both the enacted fiscal year and President's budgets, we will look for opportunities to reallocate funds to higher priority research from completed or lower priority research activities.

- Research Appropriate for ORD's External Grants Program -- Annually we will identify research needs that are appropriate for the ORD external grants program. Generally, this will be in science areas where fundamental advances to

the science are needed. Unfunded high priority research activities will be emphasized.

- Other Research Programs Where a Need May Be Met -- We will seek to identify other ORD, Federal, or private sector research programs where high priority waste research needs may be met.

- Additional Resources -- Should additional resources become available they will be allocated to high-priority unfunded or under funded research activities.

Table 3-1. Research Activities Unfunded in the Current Base Waste Research Program (**Shown in Bold**)

Research Topic Areas (In Priority Order)	RESEARCH ACTIVITIES BY RISK PARADIGM CATEGORIES					
	Risk Assessment			*Risk Management*		
	Exposure Assessment	Hazard Assessment	Risk Characterization	Remediation & Restoration	Control	Monitoring
Contaminated Sites - Ground Water	- Environmental Fate and Transport Modeling (7)* - GW Exposure Factors / Pathways (21)	**- Mixtures Toxicology (26)** - Ecological Risk Assessment Methods (38) - Human Dose- Response Models for Mixtures (3)		- Natural Attenuation (2) - Abiotic Treatment of GW (9) - Biotreatment of GW (16) **- Containment of GW (17)** - Demonstration/ Verification of Innovative Remediation Technologies (27)		- Subsurface Characterization (6) - Field and Screening Analytical Methods for GW (5) - Demonstration/ Verification of Field Monitoring Technologies (27)
Contaminated Sites - Soils / Vadose Zone	- Estimating Human Exposure & Delivered Dose (1) **- Estimating Soil Intake and Dose - Wildlife Species (3)**	- Ecological Screening Tests to Measure the Effectiveness of Treatment (18) **- Mixtures Toxicology (34)**		- Biotreatment of Soils (3) - Containment of Soils (18) - Demonstration/ Verification of Innovative Remediation Technologies (27) - Abiotic Treatment of Soils (31) - Oil Spills (36)		- Field Sampling Methods (8) - Field and Screening Analytical Methods for Soils (9) - Sampling Design (22) - Demonstration/ Verification of Field Monitoring Technologies (27)
Emissions from Waste Combustion Facilities	**- Indirect Exposure Characterization/ Modeling (13)** **- Indirect Pathway Risk Assessment Methods (11)**	**- Movement of Bioaccumulative Chemicals in Food Webs (33)** **- Dose-Response of Key Contaminants (24)**			- **Emissions Prevention and Control (12)**	- **Continuous Emissions Monitoring (CEMs) Methods (23**)
Active Waste Management Facilities	- Multimedia, Multipathway Exposure Modeling (14) - Environmental Fate and Transport; Physical Estimation (25)	- **Developing Provisional Toxicity Values for Contaminants (18**)			**- Waste Management (36)**	- Waste Characterization and Sampling (32)

* Equals the ordinal rank of each research activity across the entire Waste Research Program based on the science plus ranking factors.

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Glossary of Terms

bioavailability	The availability of a chemical to an animal, plant or microorganism. It may be assayed by measurement of uptake, toxicity or biodegradability.
biomarker	A measurable indicator of exposure or effect in a biological receptor.
biodegradation	The biological conversion of an organic compound to products of simpler structure, often inorganic products.
bioremediation	The treatment of contaminants by biodegradation to reduce their concentration.
biosensor	An analytical devices composed of a biological recognition element (e.g., enzyme, receptor, DNA, antibody, or microorganism) in intimate contact with a signal transducer (e.g., electrochemical, optical, thermal, or acoustic) which together relate the concentration or chemical property of an analyte to a measurable electronic signal.
cellular biology	The study of processes and interactions at the cellular level.
cone penetrometers	A hydraulically driven geotechnical tool for characterizing the arrangement of hydrogeologic materials.
hydrofracturing	The injection of water into contaminated consolidated sediments to create fractures which increase the permeability of the sediments, thereby increasing the effectiveness of *in situ* treatment processes.
immunoaffinity	A separation technique using

chromatography	specific antibodies to extract the target analyte(s) from an environmental or biological matrix prior to detection by immunoassay or instrumental methods.
immunoassay	An analytical method based on the interaction of a specific antibody with its target analyte(s) used for detection and quantitation. Although based on biological reagents, immunoassays are physical assays.
immunochemical method	Analytical methods based on the reaction of a specific antibody with its target analyte(s) for extraction, cleanup, concentration, detection and quantitation.
immunochemistry	A scientific discipline bordering chemistry and biology providing highly specific and precise quantitative methods for the study of environmental contaminants and human exposure assessment.
incineration	Thermal destruction of waste materials by oxidation.
in-situ remediation processes	Remediation processes that are applied "in place" in the ground, without excavation of the contaminated soil.
mechanistic data	Information describing the process of how a toxic reaction occurs in an organism.
methodological research	Research conducted to develop improved procedures to evaluate risks.
NAPL	Nonaqueous-phase liquid - a liquid consisting of organic compounds that are not completely miscible with water.
natural attenuation	Naturally-occurring processes in the environment that act without human intervention to reduce the mass, toxicity,

	mobility, volume or concentration of contaminants.
phytoremediation	Name given to set of processes that clean contaminated sites using plants.
soil horizon	A layer of soil approximately parallel to the land surface that differs from adjacent layers in physical, chemical, and biological properties or characteristics such as color, structure, texture, etc.
soil vapor extraction	The use of vapor extraction wells with blowers or vacuum pumps to remove contaminant vapors from zoned permeable to vapor flow.
solidification	Encapsulating the waste in a monolithic solid of high structural integrity.
stabilization	Converting contaminants into less soluble, mobile or toxic form.
thermal desorption	The use of elevated temperatures to remove contaminants from soils by causing them to vaporize.
toxicokinetic data	Information describing the adsorption distribution metabolism and elimination of a chemical in an organism.
vadose zone	The subsurface zone that extends between the ground surface and the ground water table.
vertical geomembrane curtain wall barrier	A vertical wall consisting of a thin, low permeability man-made material inserted in the ground to contain or divert ground water.

APPENDICES

Appendix A
Prior Waste Related Research Plans

Table A-1. Previously Developed Waste Related Research Strategies and Plans

Strategic/Research Plan	Organizing Principles	Priority Research Topics		
		High	Medium	Low
National R&D Strategy for Toxic Substances, Hazardous and Solid Wastes, CENR 1995	Risk Paradigm - Risk Assessment - Risk Management - Social and Economic Aspects of Risk Management	Only High Priority Research Identified (See Appendix A of this Plan)		
Hazardous Waste Issue Plan, ORD 1993a	Science Questions What are: - the risks posed by hazardous waste? - the most effective hazardous waste management methods? - the cost effective methods for preventing generation of hazardous waste?	- Landfills - Incineration - Site Characterization / Decision Support - Continuous Emission Monitoring - Pollution Prevention - Small Generators - Risk Characterization - Ecological Risk Assessment	- Solidification/Stabilization - Separation Technologies - Analytical Methods /QA - Hard to Manage RCRA Wastes - Exposure Assessments	- Analytical Methods - Advanced Monitoring Technologies - Inorganic 33/50 Chemicals - Large Volume/Industrial Wastes - University Research Centers

Strategic/Research Plan	Organizing Principles	Priority Research Topics		
		High	Medium	Low
Surface Cleanup Issue Plan, ORD 1993b	Topic Areas - Remediation Technology - Site Characterization, Monitoring and QA - Technical Support	- Superfund Innovative Technology Evaluation (SITE) - Alternative Treatment Technology Information Clearinghouse (ATTIC) - START - Quality Assurance - Site Characterization - Monitoring Technical Support - Treatability Study Support - Incineration	- Field Analytical Methods - *In-situ* Treatment - Separation/Extraction - Monitoring and Engineering Corrective Action - Standard Remedies	- Oil Spills - SITE Emerging Technologies - Laboratory-based Analytical Methods
Bioremediation Issue Plan, ORD 1993c	Research Categories - Site Conditions - Waste Characteristics - Biodegradation Processes - Above-ground Treatment - *In-situ* Treatment - Performance Assessment	- Site Characterization - Process Research - Pilot Scale Research - Field Research - Performance Evaluation - Modeling - Oil Spills	N/A	N/A
Ground water Issue Plan, ORD 1993d	Topic Areas - Site Characterization - Transport & Transformation - Decision Support - Decision Evaluation	- Prevention of Subsurface Contamination - Remediation of Subsurface Contamination - Subsurface Transport and Transformation - Subsurface Microbial Ecology - Ground water/Surface Water Interactions	N/A	N/A

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Appendix B
Summary of Research Needs

All the detailed research and support needs identified by the CENR, the Program Offices, Regional Offices, and the ORD are arrayed by risk paradigm in Tables B-1 through B-6 in Appendix B (one table for each element of the risk paradigm). All of these tables include data that identify the specific support or research need, the source of research need, and who/where the need should most appropriately be addressed. This set of needs is considered to be the "universe of needs" and the basis upon which ORD will determine what research is appropriate and for which it has the capability and capacity to conduct. The table attempts to identify "where" each identified research need should most appropriately be addressed. Those needs that are (or may be in the future) addressed in this plan are identified by **ORD Waste Research Plan** in bold. In many cases relevant or related research is being conducted elsewhere that will partially or fully meet the stated research need. These other locations are also identified in this same column. If there is no entry in this cell for a given research needs, research is not currently planned nor has it been identified as being conducted elsewhere.

Table B-1. Summary of Research Needs - Hazard Assessment

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Assessment Hazard Assessment	**IDENTIFICATION OF TOXIC ENDPOINTS**		
	- Greater emphasis on noncancer endpoints.	CENR OERR OSW	ORD Human Health Risk Assessment Research Plan
	- Improved understanding of the biological basis for toxicity and biologically-based extrapolation models between species.	CENR OERR OSW	**ORD Waste Research Plan**
	- Effects of short term exposure to contaminants at different ages.	CENR OERR OSW	ORD Human Health Risk Assessment Research Plan
	- Effects of dermal exposure on cancer and noncancer endpoints.	CENR OERR OSW	**ORD Waste Research Plan**
	- Effects of contaminants on ecological receptors.	CENR OERR OSW	Ecological Research Strategy
	DOSE-RESPONSE ANALYSES		
	- Biologically-based toxicokinetic models.	CENR OERR OSW	**ORD Waste Research Plan** ORD Human Health Risk Assessment Research Plan
	- Variation in susceptibilities within and across species.	CENR OERR OSW	ORD Human Health Risk Assessment Research Plan
	- Improved understanding of biological mechanisms of action at the organ, cellular, and subcellar level.	CENR OERR OSW	**ORD Waste Research Plan** ORD Human Health Risk Assessment Research Plan

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Understanding the relationship between exposure and dose, especially as it relates to bioavailability of contaminants.	CENR OERR OSW	**ORD Waste Research Plan**
	- Improved understanding of the effects of complex mixtures.	CENR OERR OSW	**ORD Waste Research Plan**
	- Development of predictive models of population dynamics for selected ecological or societal species of interest.	CENR OERR OSW	Ecological Research Strategy

Table B-2. Summary of Waste Research Needs - Exposure Assessment

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Assessment **Exposure Assessment**	**PHYSICAL ESTIMATION, TRANSFORMATION, AND FATE PROCESSES**		
	- Improve understanding of abiotic processes controlling transport, fate and bioavailability of chemicals in soil, natural waters, and sediment.	CENR	**ORD Waste Research Plan** ORD Multimedia Research Program
	- Improve understanding of bioaccumulation and metabolic processes controlling biodegradability of chemicals in microbial populations in soils, natural waters, and sediments.	CENR	**ORD Waste Research Plan,** ORD Multimedia Research Program
	- Enhancement of the MINTEQA2 database. Validation/verification.	OSW	**ORD Waste Research Plan**
	- Addition of Redox database to MINTEQA2.	OSW	**ORD Waste Research Plan**
	- Evaluation of fate and transport parameters for hazardous constituents.	OSW	**ORD Waste Research Plan** ORD Multimedia Research Program ORD Air Toxic Research Program (in part)
	- Expert analysis of biodegradation rates for the subsurface environment.	OSW	**ORD Waste Research Plan**
	- Develop a working understanding of the microbiologic and abiotic processes contributing to the degradation of contaminants in the subsurface, especially as related to natural attenuation.	OERR	**ORD Waste Research Plan**
	- Determine the environmental fate of vegetable oils and animal fats in terrestrial and freshwater ecosystems.	OERR	
	EXPOSURE PATHWAYS AND FACTORS		
	- Improve methods for diagnosing route of exposure and exposure history.	CENR	ORD Human Health Risk Assessment Research Plan (in part)

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Improve data on human activity patterns (e.g., food ingestion rates, time in various settings, etc.).	CENR	ORD Human Health Risk Assessment Research Plan (in part)
	- Better procedures / models for assessing dermal exposure, especially from soil, including matrix-specific and receptor-specific (e.g., race) properties.	CENR OERR	ORD Human Health Risk Assessment Research Plan (in part)
	- Bioaccumulation of metals, especially mercury.	OSW	ORD Human Health Risk Assessment Research Plan (in part)
	- Bioaccumulation of semi-volatile organics (chlorinated organics, PAHs, higher MW phthalates) and metals in terrestrial plants and animals, cycling of xenobiotics from terrestrial plants to detritus to soils to soil organisms.	OSW	ORD Human Health Risk Assessment Research Plan (in part)
	- Methods / models for determining the bioavailability of metals and organics from soils via the ingestion exposure route, plant to animal, animal to human (direct and indirect exposure).	OERR Regions	**ORD Waste Research Plan**
	- Guidance for determining residential exposure (dermal, inhalation) from NAPL contaminated groundwater and soils (vinyl chloride, benzene, etc.).	OERR	ORD Human Health Risk Assessment Research Plan (in part)
	- Develop methods to collect exposure data from minorities, disadvantaged populations or other groups (children , women, etc.) likely to be disproportionately affected.	CENR OERR	ORD Human Health Risk Assessment Research Plan (in part)
	- Improved understanding of exposure to dose relationships.	CENR	ORD Human Health Risk Assessment Research Plan (in part) ORD Air Toxics Research Program (in part)
	MULTIMEDIA, MULTIPATHWAY EXPOSURE MODELING		
	- Evaluate existing / developing new fate, transport, and exposure assessment models for multimedia assessments.	CENR OSW	**ORD Waste Research Plan** ORD Multimedia Research Program

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Better procedures to assess complex (e.g., multipathway / multichemical) exposure scenarios.	CENR OSW	**ORD Waste Research Plan** ORD Multimedia Research Program
	- Enhancement of OSW subsurface fate and transport models by incorporating fractured flow and heterogeneous porous media.	OSW	**ORD Waste Research Plan**
	- Validation and verification of fate and transport models in general.	OSW	**ORD Waste Research Plan** ORD Multimedia Research Program
	- DOE Spill Test Facility -- fundamental dispersion modeling research	CEPPO	
	- Research on large-scale gas releases and liquid spills under varying weather, density, terrain, and surface roughness conditions to validate and enhance exposure models.	CEPPO	ORD Air Toxics Research Program (in part)
	EXPOSURE MODELING TECHNICAL SUPPORT		
	- Fate, transport and modeling support for HWIR, OUST, OERR.	OSW OUST OERR	**ORD Waste Research Plan**
	EXPOSURE CHARACTERIZATION / MODELING - COMBUSTION / INCINERATION		
	- Correlation between combustion mercury emissions and methyl mercury levels in biomarkers.	Regions	**ORD Waste Research Plan** ORD Multimedia Research Program (South Florida Mercury Study)
	- Vapor-particle partitioning of semi-volatile organics (chlorinated dioxins and PAHs) under ambient conditions.	OSW	**ORD Waste Research Plan** ORD Human Risk Assessment Research Plan (in part) ORD Air Toxics Research Program (very little)

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Air deposition of semi-volatile organics (chlorinated dioxins, PCBs, higher MW chlorinated benzene and phenols, PAHs, and higher MW phthalates).	OSW	**ORD Waste Research Plan** ORD Air Toxics Research Program (very little)
	- Vapor transport to surfaces - wet and dry deposition.	OSW	**ORD Waste Research Plan**
	- Surface vapor uptake - plants and soils.	OSW	**ORD Waste Research Plan**
	- Mathematical models, parameter characterization, and validation of models for dry gas deposition air dispersion.	OSW Regions	**ORD Waste Research Plan** ORD Air Toxics Research Program (in part)
	- Methods for particle size distribution for input to air dispersion models.	Regions	**ORD Waste Research Plan** ORD Air Toxics Research Program (in part)
	INDIRECT PATHWAY RISK ASSESSMENT METHODS - COMBUSTION / INCINERATION		
	- Indirect eco and human exposure methodology for combustion sources (incineration / thermal desorbers).	OSW OERR	**ORD Waste Research Plan** ORD Air Toxics Research Program (in part)

Table B-3. Summary of Waste Research Needs - Risk Characterization

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Assessment **Risk Characterization**	**RISK INTEGRATION**		
	- Methods to integrate the elements of a risk assessment in complex cases.	CENR	ORD Human Risk Assessment Research Plan
	- Quantitative statistical methods to evaluate variability and uncertainty.	CENR	ORD Human Risk Assessment Research Plan
	- Methods to assess cumulative risk.	CENR	ORD Human Risk Assessment Research Plan
	- Methods to include cultural and behavioral aspects into risk analysis.	CENR	
	RISK COMMUNICATION		
	- Risk communication strategies that include community members	CENR	
	- Better statistical and communication tools to communicate risks to the public and risk managers.	CENR	

Table B-4. Summary of Waste Research Needs - Control

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Management **Control**	**WASTE COMBUSTION**		
	- Characterization of dioxin/furan emissions from boilers, especially boiler tubes and boilers of various types; and from halogen acid furnaces.	OSW	**ORD Waste Research Plan**
	- Full scale PIC testing to better understand formation dynamics; particularly post combustion PICs.	OSW	**ORD Waste Research Plan (related bench studies)**
	- Determine good combustion practices (design and operation) which will minimize emissions of priority pollutants, especially for small combustors.	OSW	**ORD Waste Research Plan**
	- Develop control techniques for mercury emissions. Improved mercury speciation.	OSW	**ORD Waste Research Plan**
	- Characterize emissions of high priority semivolatiles and Hazardous Air Pollutants from Waste combustion and develop effective control techniques.	OSW	**ORD Waste Research Plan**
	- Identification of organic and PIC surrogates for non-dioxin organics.	OSW	**ORD Waste Research Plan**
	WASTE TECHNOLOGY		
	- Research the chemical dynamics and long term efficacy of emerging waste solidification and stabilization technologies.	OSW	**ORD Waste Research Plan**
	- Evaluate treatment alternatives for wastes that contain mercury, particularly in light of air emissions and elemental mercury.	OSW	**ORD Waste Research Plan**
	- Evaluate the cross media transfer of contaminants during treatment.	OSW	**(Part of ORD tech. devel. activities)**
	- Evaluation of ground water/surface water interactions.	OSW	**ORD Eco. Protection Plan**
	- Municipal Innovative Technology Evaluation (MITE Program	OSW	
	-Guidelines: Life Cycle Management Evaluation of Waste Management	OSW	**Pollution Prevention Research Plan**

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Management Control	**POLLUTION PREVENTION & RECYCLING**		
	- Source Reduction/Recycling Options for High Priority Processes	OSW	**P2 Research Plan**
	- Technologies to Reduce Barriers to Recycling	OSW	**P2 Research Plan**
	- Source Reduction Opportunities for Combusted Wastes	OSW	
	- Criteria to Delay MACT Implementation Dates	OSW	
	- National P2 Roundtable RCRA Priorities Support	ISW	**P2 Research Plan**

Table B-5. Summary of Waste Research Needs - Remediation

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Management Remediation	**GROUND WATER REMEDIATION**		
	- Conduct field evaluations of ground water remediation technologies to obtain data on performance, cost and environmental effects.	CENR	**ORD Waste Research Plan**
	- Develop, demonstrate and evaluate *in situ* technologies, such as bioremediation, to remediate subsurface plumes.	CENR OERR	**ORD Waste Research Plan**
	- Develop technologies to characterize, model monitor and remediate contaminated plumes in ground water, particularly DNAPLs.	CENR OSWER	**ORD Waste Research Plan**
	- Identify new or improved techniques for removing or treating subsurface DNAPLs.	Regions	**ORD Waste Research Plan**
	- Develop workable site characterization protocols for evaluating the potential for using natural attenuation to meet cleanup goals in the subsurface.	OSWER	**ORD Waste Research Plan**
	- Develop understanding of microbial and abiotic processes contributing to contaminant degradation in the subsurface.	OERR	**ORD Waste Research Plan**
	- Conduct research to better understand the process associated with reactive barrier effectiveness and develop improved barrier media.	OERR	**ORD Waste Research Plan**
	- Develop improved methods of remediating ground water using vegetation planted and grown in the contaminated areas.	OERR	**ORD Waste Research Plan**
	- Develop improved methods for monitoring and evaluating performance of barriers designed to control migration of contaminated ground water.	OERR	**ORD Waste Research Plan**
	- Conduct research to understand the fate and remediation options for MTBE in fuels.	OUST	**ORD Waste Research Plan**
	- Conduct research in natural attenuation of fuels in ground water.	OUST	**ORD Waste Research Plan**
	SOIL/VADOSE ZONE REMEDIATION		
	- Conduct field evaluations of contaminated soils remediation technologies to obtain data on performance, costs and environmental effects.	CENR	**ORD Waste Research Plan**

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Develop, demonstrate, and evaluate in situ technologies, such as bioremediation, for remediation of contaminated soils.	CENR ORD	**ORD Waste Research Plan**
	- Evaluate the applicability of composting remedies to stabilization of metals in surface soils.	OERR	
	- Develop workable site characterization protocols for evaluating the potential for using natural attenuation to meet cleanup objectives in the subsurface.	OSWER	**ORD Waste Research Plan**
	- Conduct research on NA of fuels in soils and vadose zone.	OUST	**ORD Waste Research Plan**
	- Develop understanding of microbial and abiotic processes contributing to contaminant degradation in the subsurface.	OERR	**ORD Waste Research Plan**
	- Develop improved methods of remediating soil using vegetation planted and grown in the contaminated area.	OERR	**ORD Waste Research Plan**
	- Investigate the basic natural biological, chemical, and physical mechanisms that affect the toxicity or mobility of contaminants in soils to identify and optimize remediation processes.	ORD	**ORD Waste Research Plan**
	- Determine the long-term effectiveness and costs of containment systems, the proper means of monitoring them and ways to fix them effectively.	OERR	**ORD Waste Research Plan**
	-Evaluate treatment technologies for contaminated sediments.	Regions	**ORD Contaminated Sediments Work Plan**
	LANDFILLS		
	- Develop, demonstrate, and evaluate in situ technologies, such as bioremediation, for remediation of landfills.	CENR ORD	**ORD Waste Research Plan**
	- Evaluate the performance of waste containment systems at working landfills.	OERR	**ORD Waste Research Plan**
	OIL SPILLS		
	- Develop, evaluate, and demonstrate innovative technologies to remediate and restore environments impacted by oil spills or chemical releases	CENR	**ORD Waste Research Plan**
	- Evaluate the environmental impacts of oil spills remediation options.	OERR	
	REMEDIATION CLEAN UP GOALS		

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Develop techniques to measure the health of ecosystems and the effectiveness of restoration efforts.	CENR	**ORD Waste Research Plan**
	- Develop techniques for determining risk-based cleanup goals for a variety of remediation technologies.	OERR Regions	**ORD Waste Research Plan**
	BETTER MANAGEMENT DECISIONS		
	- Develop new information management and quality assurance tools and procedures to improve the speed with which data are collected, tracked, interpreted and reviewed at sites.	CENR	
	- Provide site-specific technical support, including in-depth support that deals with complex remediation problems.	OSWER	**ORD Waste Research Plan**
	- Provide support for the development of Presumptive Remedies (guidance to speedy remedy selections and promote technically sound, consistent selections).	OERR	**ORD Waste Research Plan**
	- Expand bioremediation field data base to include composting.	OERR	**ORD Waste Research Plan**
	- Direct research and development expertise towards solving site-specific cleanup problems.	OERR	**ORD Waste Research Plan (technical support)**
	- Provide site-specific technical assistance on the application of subsurface modeling at contaminated sites, especially to address cleanup technical impracticability and the applicability of natural attenuation.	OSWER	**ORD Waste Research Plan**
	- Develop methodologies for evaluating the outcomes, or benefits, of cleanup projects.	OERR	
	- Develop tools and provide guidance on how to estimate costs of remediation projects to support cleanup decisions and justify budget requests.	OERR	**(to be determined)**
	- Develop and implement ways to ensure that recent scientific/engineering advances can be rapidly and correctly implemented in remediation practice.	ORD	**ORD Waste Research Plan**
	- Develop means to keep remediation stakeholders informed about state-of-the-art solutions to the highest priority technical problems.	ORD	**ORD Waste Research Plan**
	-RCRA CA Tech Support - Remediation	OSW	**ORD Waste Research Plan**
	FEDERAL FACILITIES		

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Conduct field evaluations of technologies to remediate radioactive wastes and mixed wastes in order to obtain data on performance, cost and environmental effects.	CENR	**DOE**
	- Develop a national federal test site program at federal facilities to support technology development and evaluation.	CENR	**DOD, DOE**
	- Develop, demonstrate, and evaluate innovative technologies for characterization, identification, and remediation of energetic materials (e.g., unexploded ordinances (UXO) and chemical munitions).	CENR	**DOD**
	- Coordinate development of robotics waste separation and characterization technologies that are applicable to high-level waste, mixed wastes, landfills and contaminated soils, and ground water contaminated plumes.	CENR	**DOE**

Table B-6. Summary of Waste Research Needs - Monitoring

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
Risk Management **Monitoring**	**FIELD SAMPLING METHODS**		
	- Innovative site characterization (especially and related to VOCs, metals, and natural attenuation).	OERR	**ORD Waste Research Plan**
	FIELD AND SCREENING ANALYTICAL METHODS		
	- Speciation of arsenic and selenium.	OSW	**ORD Waste Research Plan**
	- Evaluation of pesticide screening by GC/atomic emission detection.	OSW	**ORD Waste Research Plan**
	- Direct determination of PAHs by capillary electrophoresis with laser-induced fluorescence detection.	OSW	**ORD Waste Research Plan**
	- Lower analytical detection limits for bioaccumulative chemicals.	OERR	**ORD Waste Research Plan**
	- Develop a wider spectrum of immunoassay tools and methods for soil screening.	Regions	**ORD Waste Research Plan**
	- Improve data on contaminant levels and release rates from sites, especially field analytical methods.	CENR OERR	**ORD Waste Research Plan** ORD Drinking Water Research Program (in part) ORD Air Toxics Research Program (in part)
	- Improve TCLP, especially for oily wastes.	Regions	
	- Develop corrosivity and ignitability tests for solids.	Regions	
	CONTINUOUS EMISSION MONITORING (CEMs) METHODS		
	- Analytical methods for chloro- and bromo- dioxins and furans. Air, soils, waste residue, continuous emission monitors (CEMs) for combustion sources.	OSW	**ORD Waste Research Plan**
	- Develop guidance or improve analytical methods for better speciation of organics (PICs).	OSW	**ORD Waste Research Plan**
	- CEMs for mercury and mercury species.	OSW	**ORD Waste Research Plan**

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- Improved surrogates for emissions of PIC HAPs and associated CEMs.	OSW	**ORD Waste Research Plan**
	- Lower detection limits of VOST methods for PICs.	OSW	**ORD Waste Research Plan**
	- Improved discrimination of coeluting PIC peaks.	OSW	**ORD Waste Research Plan**
	- Inexpensive monitors for good combustion conditions for small units.	OAQPS	**ORD Waste Research Plan**
	- Improvement to the Total Organic Emissions Test (TOE).	Regions	**ORD Waste Research Plan**
	DEMONSTRATION & VERIFICATION OF FIELD MONITORING AND CHARACTERIZATION TECHNOLOGIES		
	- Demonstration of innovative monitoring and site characterization technologies.	OERR TIO	**ORD Waste Research Plan**
	SPATIAL ANALYSIS AND OPTIMIZED SAMPLING DESIGNS		
	- Innovative site characterization. (especially as related to natural attenuation).	OSW OUST OERR	**ORD Waste Research Plan**
	SURFACE / SUBSURFACE CHARACTERIZATION TECHNOLOGY DEVELOPMENT AND EVALUATION		
	- Innovative site characterization. (especially as related to natural attenuation).	OSW OUST OERR Regions	**ORD Waste Research Plan**
	- Develop innovative techniques for locating DNAPLs in the subsurface.	OERR	**ORD Waste Research Plan**
	- Develop methods for monitoring and evaluating the performance of barriers designed to control migration of contaminated groundwater, especially DNAPLs.	OERR	
	MONITORING AND CHARACTERIZATION TECHNICAL SUPPORT		
	- Technical support on sampling and analysis and CEMS for PICs, metals, and PM.	OSW	**ORD Waste Research Plan**

Risk Assessment Element	Research Needs Sorted by Major Research Activities	Source of Research Need	Who/Where Will Need be Addressed
	- RCRA corrective action technical support.	OSW	**ORD Waste Research Plan**
	- Superfund site-specific monitoring and characterization (including remote sensing) technical support.	OERR Regions	**ORD Waste Research Plan**
	- Training courses: fate and transport of contaminants and DNAPLs	Regions	

Appendix C

Related Research Programs

Related Research in the Office of Research and Development

Hazardous Substances Research Centers

The competitive Hazardous Waste Research Centers were created as a result of the CERCLA amendments of 1986 (P.L. 99-499). Section 311, Research, Development, and Demonstration of the reauthorization directs EPA to " ... make grants to institutions of higher learning to establish and operate not fewer than five hazardous substance research centers in the United States. In carrying out this program the Administrator should seek to have established and operated 10 hazardous substances research centers in the United States." The legislation goes on to say responsibilities shall include at least research and training related to the manufacturing, use, transportation, disposal, and management of hazardous substances and publication and dissemination of the results of the research. The focus of each center is to parallel problems within the geographic regions of the Centers.

ORD currently is supporting 5 HSRCs through either base resources or Congressional directive. The Centers draw financial support through EPA, other federal agencies, academia, states, local communities and the private sector. The following table identifies the centers, their focus and their participating members.

Center Name	Center Focus	Consortium Members
Northeastern HSRC	Industrial Waste o Incineration/thermal treatment o Characterization and monitoring o *In situ* remediation o *Ex situ* treatment processes	MIT, New Jersey Inst. of Tech, Rutgers, Princeton, Stevens, Tufts, Univ. of Med and Dentistry of NJ.
Great Lakes and Mid-Atlantic HSRC	*In situ* Bioremediation o In-situ bioremediation technology o Surfactant introduction tech. o Bioventing	U. of Michigan, Howard U., Michigan State
Great Plains/Rocky Mountain HSRC	Contaminated Soils and Mining Wastes o Soil and water contaminated with heavy metals o Soils and groundwater contaminated by organic chemicals o Wood preservatives that contaminate water o Pesticides identified as haz. waste o Improved tech. and methods to characterize and analyze contaminated soils o Waste minimization and P2 methods and technology	Kansas State U., Haskell Indian Nations U., Lincoln U., Montana State U., South Dakota State, U. of Iowa, U. of Missouri, U. of Montana, U. of Nebraska, U. of Wyoming, U. of Northern Iowa, and Utah State U.
South and Southwest HSRC	Contaminated Sediments o *In-situ* chemical mobilization processes in bed and confined disposal facilities o *In-situ* remediation o *In-situ* detection	Louisiana State U., Georgia Inst of Tech. , Rice U.
Western HSRC	Groundwater Cleanup and Site Remediation o Chlorinated solvents o Halogenated aromatic compounds o Nonhaloginated aromatics including petroleum derivatives o Ordnance wastes o Heavy metals o Evaluation of factors affecting the transport and fate of chemicals in the environment o Design and management issues for site remediation	Stanford U., Oregon State U.

Minority Centers

Two minority centers are currently funded: Southern University at Baton Rouge and University of Texas - El Paso. Both existing Centers are currently funded from within the Waste programs.

Center Name	Center Focus	Consortium Members
Center for Environmental Resources Management	o Problems that effect low income individuals and groups o Minority residents of the Mexico boarder region o Strengthen the capability of Hispanics to enter environmental careers	U. of Texas El Paso
Institute for Env. Issues and Policy Assessment Center for Energy and Env. Studies	o P2 o Environmental Equity o Mississippi River Env. Strategy o Environmental Risk	Southern U. at Baton Rouge

Small Business Innovations Research (SBIR)

Small Business Innovations Research is a Federal wide congressionally mandated program which is funded through a set-aside of 2.5 percent of extramural research funds appropriated within an agency. The general focus of this contract program is spread across all media. The programs primary focus is on cleanup, resulting in proof of concept and actual demonstration of individual entrepreneurs technologies, many of which have application to remediation.

The most current topic areas being pursued are addressed in the following table.

SBIR FY 1997 Topic Areas
Drinking Water
Municipal and Industrial Wastewater Treatment and P2*
Wet Weather Flow Treatment and Pollution Control
Prevention and Control of Indoor Air Pollution
Prevention and Control of NOx, VOC's, SO2, and Toxic Air Emissions*
Treatment, Recycling, and Disposal of Solid Wastes , Hazardous Wastes and Sediments*
In situ Site Remediation of Organically Contaminated Soil, Sediments and Groundwater*
Treatment or Removal of Heavy Metals at Contaminated Sites*
Pollution Prevention*
Advance Monitoring and Analytical Technologies*

* Of probable interest to the waste plan and clients

Companion ORD Research Plans

The Waste Research Plan is one of 10 separate plans being developed by ORD. It would not be unexpected for an individual client to find relevant information in one or more of the companion plans. Hence, attached is a list of those plans, a short synopsis of the focus of each, and the lead for development of the plan.

Companion Plan Titles	Short Synopsis of Plans Focus	ORD Lead
Drinking Water Disinfection/DBPs	The continued occurrence of waterborne disease outbreaks demonstrates that contaminated drinking water (DW) with bacteria, viruses and parasites still poses a serious health risk when treatment is inadequate. A large number of disinfection-by-products (DBPs) have been identified resulting from the disinfection of DW source waters. These DBPs have the potential to cause adverse health effects in the exposed public. The key areas of research will focus on: assessing the health effects from exposure of waterborne pathogens and DBPs; the assessment of the potential exposures of pathogens and DBPs in various US populations, esp. in susceptible populations; assessing the risks from pathogen and DBP exposures and comparing the trade-offs between risks; and determining cost-effective technologies to treat source waters to achieve low pathogen and DBP concentrations in final consumer DW.	ORSI, Gail Robarge, 202-260-9101
Particulate Matter	The overarching mission of EPA's Particulate Matter (PM) research program is to provide an improved scientific basis for future regulatory decisions concerning public health risks posed by airborne fine particles. The areas of PM2.5 health effects research that need to be addressed to effect these decisions and implementation activities are as follows: 1) development of a more complete interpretation of the PM epidemiologic data; 2) an understanding of the biological mechanisms of PM2.5 in order to explain the observed effects, the reported independence of effects from particle composition, and the lack of an obvious threshold for effects (i.e., every exposure concentration may cause an effect in some individuals in the population); and 3) an understanding of the composition, size, physical properties, and sources of PM2.5 that may cause health effects.	NCEA, William Farland, 202-260-7316
Arsenic in Drinking Water	The current arsenic drinking water MCL is 50 ug/L and was set in 1942 by the Public Health Service. This MCL is not based on health risk assessments as we now set MCLs. The key areas of research will focus on: 1) the development of cost effective arsenic control technologies for small drinking water systems; 2) development and validation of analytical methods to speciate arsenic in water, soils, foods and biological tissues; 3) assessment and risk characterization of human and animal studies for arsenic exposures; and 4) effects research on cancer and noncancer health effects, mechanisms of action and human susceptibility.	NCEA, William Farland, 202-260-7316
Endocrine Disruptors	At present, the hypothesis that endocrine disrupting chemicals are causing adverse health in the wildlife and humans remains an intriguing hypothesis. Most of our knowledge and concerns to date have arisen from situations with relatively high level exposure to persistent organic pollutants or therapeutic use of pharmacological agents. For proper regulatory action to occur, we must increase our understanding of the potential scope of endocrine disruption in humans and wildlife, including: define the range of health effects, critical life stages, sensitive species, and exposures relevant to alterations in endocrine function; and develop risk management options to reduce or prevent additional adverse effects in populations.	NHEERL, Robert Kavlok, 919-541-2326

Companion Plan Titles	Short Synopsis of Plans Focus	ORD Lead
EMAP	This program develops the science of measuring ecosystem health and for monitoring the condition and trends of our natural resources at the regional scale. Using the CENR National Monitoring Framework and interagency workgroups as guides, EMAP supports complementary intramural and extramural (STAR) research programs to develop more cost-effective ecological indicators, and to design multiple-tier monitoring methods capable of detecting trends and associating ecological impacts with likely stressors. The indicators and monitoring designs intended to support state, regional, and national-level environmental report cards encompass multiple stressors and many resource classes such as estuaries, streams, lakes, wetlands, forests and grasslands.	NHEERL, Gil Veith, 919-541-4130
Human Health Risk Assessment	Areas of research focused on by this plan are designed to advance the state of Human health risk assessment, and to develop quantitative tools and methods. They are: Human Exposure measurements and models; cumulative risk; risk for vulnerable populations; risk for less-than-lifetime-exposures; mechanistic data in risk assessment; stakeholder activities related to community-based exposure and risk and, technical support and training.	NHEERL, Dale Paul, 401-782-3037
Ecosystems Protection	In virtually every major environmental act, Congress has required EPA not only to protect human health but also the environment. This document provides the strategic direction and priority research objectives for the ORD's Ecological Research Program. The goal of the program is to provide the scientific understanding required to measure, model, maintain and/or restore, at multiple scales, the integrity and sustainability of ecosystems now, and in the future. Fundamental research areas include monitoring, modeling, assessment, remediation, and restoration. Specific problems of importance discussed in the document include ecological research on: ozone, acid deposition, ecocriteria, wet weather flow, pesticides, hazardous waste, global change, endocrine disruptors, UV-B, contaminated sediments, exotic species, habitat alteration and restoration, and regional risk assessment.	NERL, Rick Linthurst, 919-541-4909
Global Change	Based on the findings of the Intergovernmental Panel on Climate Change, guidance in the Office of Research and Development's (ORD) strategic plan, and the priorities specified in the FY 1997 Our Changing Planet by the US Global Change Research Program (USGCRP), ORD will strategically invest in global change research. ORD's Global Change Research Program will focus on ecological vulnerabilities of ecosystems to climate change, the implications for human health, and mitigation and adaptation approaches. The research conducted will provide policy makers with information on potential ecological and human health consequences of climate change and technical data needed to evaluate alternative GHG emission reduction and adaptation approaches.	NERL, Tom Barnwell, 706-546-3180

Companion Plan Titles	Short Synopsis of Plans Focus	ORD Lead
Pollution Prevention*	For pollution prevention to be a success, all stakeholders (e.g., regulators, industry, environmental groups) must have access to scientifically-sound pollution prevention technologies and approaches. They must also be able to measure and objectively evaluate the viability and comparative environmental performance of these pollution prevention technologies and approaches. There is a lack of user-friendly tools and methods to compare pollution prevention solutions with each other, and to end-of-the-pipe solutions, and there is also a lack of proven pollution prevention technologies and approaches for many pollutant sources in a number of economic sectors. Research is being undertaken in pollution prevention to address fundamental knowledge gaps in both of the above areas -- tools and methods, and technologies and approaches.	NRMRL, Jon Herrmann, 513-569-7839

* Described below in more detail due to the significant linkages to the waste plan and clients.

Pollution Prevention Research

Since the early 1990s, ORD's pollution prevention research and development program has been transformed from an extramurally-focused effort which promoted pollution prevention using targeted technical assistance and information transfer, to an in-house-focused effort which is devoted to scientific and technical research on pollution prevention tools, methodologies, technologies, and approaches. While this transformation has not been seamless, it is well underway and will continue into the foreseeable future. Concomitant with a shift to an in-house research and development program, resource allocations have been reduced and targeted at support (i.e., infrastructure) that provides post-doctoral researchers, Master's-degree assistants, technicians, and analytical services with which to build the in-house capabilities of ORD scientists and engineers. This shift has caused ORD to reevaluate its pollution prevention priorities and to focus on a smaller set of high priority activities where it can make a significant contribution based on its unique expertise and capabilities.

In preparing the Pollution Prevention Research Strategy, it was essential that the above reorientation be given full consideration, and that a research and development program in pollution prevention be targeted at and supportive of building and strengthening ORD's in-house capabilities. As a result, four long-term goals have been identified and will be pursued:

> ***I. ORD will develop, test, and provide user-friendly tools and methodologies that permit individuals and organizations to improve decision making related to reducing or eliminating the generation of emissions, effluents, and wastes from products, processes, and activities.***

II. ORD will develop and test technologies and approaches that are broadly applicable in preventing pollution across economic sectors, and evaluate products, technologies and approaches that are targeted at preventing high priority human health and environmental problems in support of the Agency's regulatory and compliance programs.

III. Through its Environmental Technology Verification Program (ETV), ORD will serve as a catalyzing organization to propel into the marketplace the most promising commercial-ready pollution prevention products and technologies from both the public and private sectors.

IV. Through its extramural grants program, ORD will support social science research in the areas of environmental economics and decision making to foster the adoption of pollution prevention by the public and private sectors at all levels.

ORD believes that pollution prevention progress in the next ten years will not proceed as rapidly as in the past ten, but that the results of that progress can be even more significant. The "next wave" of pollution prevention can provide economic and environmental benefits in a host of situations. Since these advances will likely represent more fundamental changes in individual lifestyle, industrial process design (e.g., clean technologies), consumer products (e.g., benign chemicals), and land use, future research and development must focus on quantum leaps instead of incremental improvements. ORD will only be able to sustain this future direction if it concentrates on longer-term research which will produce a new generation of tools and technologies that move pollution prevention beyond the obvious and less formidable opportunities of the past.

Related Research Sponsored by the Office of Solid Waste and Emergency Response

OSWER provides resources to ORD and non-ORD entities for research of particular emphasis for their programs. Funding to any single project may be one time only or may be part of a longer term commitment. In the paragraphs below, several research areas that have been funded and identified by OSWER are described.

- Chemical Emergency Preparedness and Prevention Office (CEPPO)
  Analysis of emergency gas release data: CEPPO is providing funds under the Clean Air Act through the National Oceanic and Atmospheric Administration (NOAA) to the Desert Research Institute (DRI) for analysis of emergency gas release data collected at the Nevada Test Facility. The original data were generated by research work funded by ORD under the Clean Air Act; however, funding was terminated in September 1995. The data is critical to industry and others to validate dispersion modeling approaches to support hazard and risk assessments for the prevention of catastrophic accidental releases.

Catastrophic accidental release: At the Wharton School of the University of Pennsylvania, CEPPO-funded research projects are in progress on issues associated with catastrophic accidental release risk assessment, risk management, risk decision-making and accident investigation.

Catastrophic release of propane gas: Under a cooperative agreement with CEPPO, the State of Delaware is developing a model risk management program and plan for propane, including the modeling and assessment of the consequences of catastrophic releases of propane gas.

Chemical accident prevention: Under a cooperative agreement with CEPPO, the National Institute for Chemical Studies is conducting outreach, training, and technical assistance in chemical accident prevention, addressing particularly small businesses and local communities, and focusing on issues of Clean Air Act section 112 (r) and 507. They are also analyzing local state and federal chemical accident investigation reports to highlight problem areas, trends and significant findings.

- Office of Underground Storage Tanks (OUST)

Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide For Regulators, EPA 510-B-97-001 - OUST is currently developing a manual that will help state and federal underground storage tank (UST) regulators evaluate and promote expedited site assessments. The manual will cover five major UST site assessment issues: the expedited site assessment process, geophysical methods for UST site investigations; soil gas surveys; direct push technologies; and field analytical methods for petroleum hydrocarbons. The equipment and methods presented in the manual will be evaluated in terms of applicability, advantages, and limitations for petroleum UST sites. OUST anticipates the manual will be available in March 1997.

How to Effectively Recover Free Product At Leaking Underground Storage Tank Sites: A Guide For State Regulators, EPA 510-R-96-001, September 1996 - This manual assists regulators in determining when recovery of free product is necessary, whether an appropriate recovery method has been proposed, and whether the free product recovery plan provides a technically sound approach. (This manual was done in conjunction with NRMRL, but was published as an OUST document).

How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers, EPA 510-B-95-007, May 1995 - This manual has been proposed, and whether the corrective action

plan provides a technically sound approach to achieve cleanup. It covers 10 technologies.

- Office of Solid Waste (OSW)

  Risk Assessment -- Exposure scenarios for wastes in-commerce - Hazardous wastes are increasingly being recycled and the products from these recycling operations are finding their way into commerce and use by the public. Consequently, these materials have a number of unique attributes that require special evaluation. In particular, this work is concerned with the long term stability of constituents in stabilized matrices, the bioavailability of constituents under different conditions, and the development of models for exposure pathways that are not typical of waste management scenarios. This work is being conducted by OSW and its contractors.

  Monitoring -- Continuous emission monitors - In cooperation with the Department of Energy, OSW is researching and evaluating the long-term ruggedness of CEMs for mercury and other organics. These monitors, while used in Europe, have not been installed extensively in the United States. This effort involves researching the long-term performance and stability of these state-of-the-art monitors.

  Formation of products of incomplete combustion (PIC) - Field sampling efforts have been underway over the last several years to evaluate the nature and extent of organic hazardous constituents that form as a result of incomplete combustion. In cooperation with cement producers, OSW has conducted a series of field studies to assess PICs in cement kilns.

  Accelerated microwave extraction - In conjunction with Environment Canada, OSW is developing a microwave extraction method for organic compounds. OSW is continuing to develop the method and will conduct a round-robin study in order to evaluate and improve the performance of this method.

  Fate and Transport Model Development -- Groundwater contaminant movement modeling - Although ORD makes significant contributions to this area, OSW, with its specialized contractors and other academic experts, conducts development work to improve EPA's Composite Model for Transformation Products. OSW is presently working to restructure the Monte Carlo framework in the model so that we can separate model uncertainty from data variability. In addition, in conjunction with several industries, academic experts and the ORD, OSW will be reevaluating available subsurface biodegradation data.

Multimedia and indirect fate and transport modeling - In close coordination with ORD, as outlined in the draft Multimedia Science Plan, OSW is taking the lead on a number of areas; examples include the development of additional human health and ecological endpoints for new chemicals, refinement of the waste management units which describe the source of contaminants, revisions to several submodels including the overland flow model, and additional evaluation of loss processes.

Environmental Benefits Analysis -- Contingent valuation of groundwater - OSW is restarting an effort to evaluate the nonuse economic benefits of avoiding groundwater contamination. This effort, being conducted in conjunction with OSW's specialized contractors, will use the controversial method of contingent valuation. Prior SAB review and additional peer review input has led to a strategy that requires some experimental testing of responses to validate the valuation information that OSW us acquiring.

- Office of Emergency and Remedial Response (OERR)

MARSSIM (ORIA - lead): MARSSIM is a 750- page guidance document which addresses issues related to the proposed rule, "EPA Radiation Site Cleanup Regulation," such as how to set background levels and risk/method/decision confidence levels.

MARLAB (ORIA-lead): MARLAB is a document concerning analytical methods, especially measurement issues related to the Radiation Site Cleanup proposed rule.

Fact Sheets for Groundwater/Modeling (and future potential EPA/DOE/NRC Interagency Modeling Working Group) (ORIA-lead): Four reports promoting modeling of hazardous and radioactive waste sites were completed and published by ORIA. Four fact sheets were prepared summarizing the reports:

- Environmental Characteristics of EPA, NRC, and DOE Sites Contaminated with Radioactive Substances.
- Computer Models Used to Support Cleanup Decision-Making at Hazardous and Radioactive Wastes Sites.
- Environmental Pathways Models - Groundwater Modeling in Support of Remedial Decision Making at Sites Contaminated with Radioactive Material.
- A Technical Guide to Groundwater Model Selection at Sites Contaminated with Radioactive Substances.

Groundwater/Modeling Document Review (and future potential EPA/DOE/NRC Interagency Modeling Working Group) ORIA-lead): Two documents on modeling were prepared:

- An Evaluation of Three Representative Multimedia Models Used to Support Cleanup Decision-Making at Hazardous, Mixed and Radioactive Waste Sites.
- A Recommended Guide to Documenting Groundwater Modeling Results at Sites Contaminated with Radioactive Substances.

The Kd Model and Its Use in Containment Transport Modeling: A multi-Agency workgroup is developing a guidance document concerning the distribution coefficient for groundwater modeling at sites, including mixed waste sites.

Estimation of Water Flux in the Unsaturated Zone - A Survey of the Available Techniques: A multi-Agency workgroup to develop a guidance document for groundwater modeling at sites, including mixed waste sites.

International Containment Conference: Technical conference for complex waste sites, including mixed waste sites.

Decision Support System: ORIA and OERR are funding delivery of a probabilistic decision tool for all waste sites, including mixed wastes sites. Product developed in conjunction with Sandia National Laboratory.

- Technology Innovation Office (TIO)

Ground-Water Remediation Technologies Analysis Center (GWRTAC) -- The GWRTAC was established in 1995 through a cooperative agreement between TIO and the National Environmental Technology Applications Center (NETAC). NETAC's overall mission is to facilitate the development and use of new groundwater technologies through: improving understanding and deployment of innovative groundwater remediation technologies; supporting customer groups requiring access to this technology developers and users. Current activities include assembling information to be included in case study and vendor information databases, placing the databases on the Internet, preparing technology status reports, and responding to requests for information on groundwater technologies (See attached fact sheets for further information).

Remediation Technologies Development Forum (RTDF) - The RTDF was established by EPA in 1992 and now includes a consortium of partners from industry, government agencies, and academia. RTDF's overall mission is to foster public-private partnerships to advance the development of more permanent-cost-effective technologies for the remediation of hazardous wastes. The RTDF works to achieve this goal through: identifying priority remediation technology development needs; establishing and overseeing action teams to plan and implement collaborative research projects to address remediation

problems; and addressing scientific, institutional, and regulatory barriers to the use of innovative treatment technologies.

Five Action Teams have been formed within the RTDF to address priority research areas: Lasagna Consortium, Bioremediation Consortium, Permeable Barriers Action Team, In -Place Inactivation and Natural Ecological Restoration (INERT) Soil-Metals Action Team, and Sediments Remediation Action Team. Participants in each team provide funding and/or in-kind support for specific research efforts of the team.

TIO provide funds for the staff and contractors needed to support the logistics of running the forum (e.g., organizing meetings and conference calls). The research support currently provided by EPA through its participation on the RTDF teams is provided by ORD.

Research Conducted/Sponsored by other Agencies and Departments

Major waste research programs exist in other agencies and departments. The purpose of this section is to acknowledge and identify those programs. As described below in the body of this report, an important consideration for prioritization of waste research to be performed by EPA/ORD is the extent to which a research issue is being addressed elsewhere. Depending upon the particular research need, a small, sharply focused ORD effort might have significant impact even if another agency has a large research program addressing an apparently similar research issue. In addition, ORD's position as part of the lead environmental regulatory agency puts the Office in a unique leadership role for the research programs of others. On the other hand, it may be that, given the nature of the issue and the resources directed towards it by other agencies, ORD might more wisely focus its resources elsewhere.

The description of eight other government programs follows. Each gives a brief indication of the mission, magnitude, scientific direction and sharpness of focus, of programs in other agencies/departments to determine the extent to which ORD efforts might be complementary, synergistic, duplicative or relatively inconsequential. Where possible, an Internet address is provided as a pointer to more information about these other programs.

- The Department of Energy (DOE)'s Office of Health and Environmental Research (OHER) operates an Environmental Remediation Research program, which is focused on developing an understanding of the fundamental physical, chemical, geological, and biological processes that must be marshaled for the development and advancement of new, effective, and efficient processes for the remediation and restoration of the Nation's nuclear weapons production sites [http://www.er.doe.gov/production/oher/habir/cover.html]. A primary effort is a

comprehensive research program in bioremediation that integrates the full range of fundamental scientific disciplines necessary to advance this emerging technology. DOE-OHER's natural and accelerated bioremediation research program is designed to promote the use of living organism to reduce or eliminate waste. The microbial genome research program is designed to provide genome sequence and mapping data on microorganisms of industrial importance and on those that live under extreme conditions. The environmental technology partnerships program is intended to encourage university, national laboratory, and industrial partnerships to address fundamental bioremediation and integrated assessment research that is oriented toward reducing waste production and energy consumption in manufacturing processes. The subsurface science program is designed to understand the physical, chemical, and biological processes controlling the fate of complex chemical mixtures released to terrestrial subsurface environments; and research in the deep terrestrial biosphere.

The Department of Energy's Office of Environmental Management (www.em.doe.gov) is responsible for environmental restoration, waste management, technology development, and facility transition and management. The Office of Science and Technology (OST) (em-50.em.doe.gov) has the responsibility for developing better, faster, cheaper, and safer technologies for meeting DOE's 30-year goal for environmental restoration and waste management, and for managing crosscutting activities. OST administers research in four Focus Areas:

- Tanks (http://em-50.em.doe.gov/BEST/FA/tanks/tanks.html)
- Subsurface Contaminants (Integration of Plumes and Landfills) (http://em-50.em.doe.gov/BEST/FA/scfa/scfa.html)
- Decontamination/Decommissioning (http://em-50.em.doe.gov/BEST/FA/DD.html)
- Mixed Waste (http://em-50.em.doe.gov/BEST/FA/mw/mixedwaste.html)

It also manages three crosscutting research programs:

- Characterization, Monitoring and Sensor Technology (CMST) (http://em-50.em.doe.gov/BEST/FA/CMST.html)
- Robotics (http://em-50.em.doe.gov/BEST/FA/robotics.html)
- Efficient Separations (http://em-50.em.doe.gov/BEST/FA/ES.html)

- The Strategic Environmental Research and Development Program (SERDP) is a multi-agency program created in 1990 through Public Law 101-510, and funded through the DoD [http://www.wes.army.mil/serdp/home/html]. As such it responds to environmental requirements of the DoD and those that the DoD shares with the DOE, the EPA, and other government agencies. The program

seeks to identify, develop, demonstrate, and transition technology from six thrust areas: cleanup, compliance, conservation, pollution prevention, energy conservation/renewable resources, and global environmental change. In FY96, SERDP was funded at about $58M, of which 30 percent, or about $17M, was for cleanup research.

The SERDP cleanup thrust area focuses on conducting R&D to achieve more efficient and effective environmental cleanup of soil, sediment, ground water, surface water and structures already contaminated by past practices with hazardous materials (including unexploded ordnance), radioactive (low-level or mixed wastes) and toxic substances. The principal focus of this area is more cost-effective cleanup/remediation techniques and technologies, monitoring and characterization methods and technologies, and assessment methods.

- The National Institute of Environmental Health Sciences (NIEHS) manages a large basic research program directed towards Superfund issues [http://www.niehs.nih.gov/sbrp/home.htm]. The program is mandated in CERCLA (Section 209), which establishes a "basic university research and education program" in NIEHS, and further reinforced in SARA (Title III, Section 311), where the intent of Congress is clarified, indicating that the program "may include" the following: epidemiologic and ecologic studies, advanced techniques for detection, assessment and evaluation of effects on human health of hazardous substances; methods to assess the risks to human health presented by hazardous substances; and methods and technologies to detect hazardous substances in the environment and basic biological, chemical, and physical methods to reduce the amount and toxicity of hazardous substances.

  NIEHS grants in this program are generally for a 5-year period, so new Request for Assistance (RFAs) are only developed once every 5 years or in the event significant new resources are appropriated in a particular fiscal year. Annual funding has been averaging about $35M/year. Projects supported include analytical chemistry, biomarkers, bioremediation, combustion engineering, ecology, epidemiology, exposure assessment, fate and transport, human health effects, and non-biological remediation. The most recent RFA was issued in FY94.

- The Agency for Toxic Substances and Disease Registry (ATSDR) (http://atsdr1.atsdr.cdc.gov:8080/atsdrhome.html) was created by CERCLA with broad mandates including: Superfund site public health assessments, health investigations, surveillance and registries, applied research, emergency response, health education, and toxicological database development. As part of its mandate, ATSDR is required to prepare toxicological profiles of agents found

commonly at Superfund sites, including identifying data gaps and research needs. ATSDR is further directed to ensure the development of an applied research program to address data gaps identified in the toxicological profiles. In FY1996, ATSDR directed approximately $16 million to addressing its "substance-specific mandates", including identification of priority hazardous substances, development of toxicological profiles on those substances, and research to answer major unknown questions about health effects.

ATSDR applied research serves two major functions: (a) to respond to the public's concern, has human exposure to hazardous substances occurred and resulted in adverse health effects?; and (b) to provide EPA with critical health-based information so that cleanup decisions that are effective and protective of public health can be made. ATSDR's in-house research capability resides primarily in the area of human studies in communities at and around waste sites. ATSDR supports the Association of Minority Health Professions Schools, as directed by the Congress, to fill some data gaps identified in its toxicological profiles. Other data gaps ATSDR hopes will be filled on an "volunteer" basis by industry, or by EPA (through TSCA and FIFRA authority), NIH and the National Toxicology Program (NTP).

- The United States Geological Survey (USGS), as described in a recent National Research Council review (*Hazardous Materials in the Hydrologic Environment: the Role of Research by the U.S. Geological Survey*, National Academy Press, 1996) has a number of programs in which studies are conducted to aid in resolving problems related to the contamination of surface and ground waters by hazardous materials. The Toxic Substances Hydrology Program [http://wwwrvares.er.usgs.gov/nrp /proj.bib/wood.html] is one such program. Areas of research focus on the fate and transport of contaminants and bioremediation and natural attenuation of contaminants, especially for petroleum sources. The USGS has worked with ORD researchers at some Superfund sites.

- The Department of Defense's Office of Environmental Security (DODOES) sponsors the Environmental Security Technology Certification Program (ESTCP) (http://www.acq.osd.mil/ens/estcp/main.html). ESTCP's goal is to demonstrate and validate promising, innovative technologies that target the Department of Defense's (DoD's) most urgent environmental needs. These technologies provide a return on investment through cost savings and improved efficiency.

  The current cost of remediation and compliance in the DOD is significant. Innovative technology offers the opportunity to reduce costs and environmental risks. ESTCP's strategy is to select lab-proven technologies with broad DoD

and market application. These projects are aggressively moved to the field for rigorous trials that document their cost, performance, and market potential.

ESTCP Demonstrations - Successful demonstration leads to acceptance of innovative technologies by DoD end-users and the regulatory community. To ensure that the demonstrated technologies have a real impact, ESTCP incorporates these players in the development and execution of each technology. ESTCP demonstrations—

- Address real DoD environmental needs.
- Significantly reduce costs and risks and expedite implementation.
- Document and validate the cost and performance of new technologies for DoD end-users and the regulatory community.

- The Rapid Commercialization Initiative (RCI) (http://rci.gnet.org/) is a federal/state/private cooperative effort to expedite the application of new environmental technologies. The participating federal agencies include the Department of Commerce, Department of Defense, Department of Energy and the Environmental Protection Agency; participating states and state organizations include The State of California Environmental Protection Agency, Southern States Energy Board, and the Western Governors Association. The program makes use of cooperative demonstration projects to identify barriers to the acceptance and use of new technologies; once identified, these barriers will be removed, where possible. The program consists of 10 individual projects each of which will be demonstrating a different environmental technology. The main goals of the program are to identify and reduce the barriers that impede market entry of new technologies. It is the opinion of many technology developers and users, environmental groups, prospective investors and the states, that environmental technologies face a set of unique barriers stretching from initial demonstration to final market entry that make commercialization specially difficult.

- The Interstate Technology and Regulatory Cooperation Working Group (ITRC) (http://www.gnet.org/gnet/gov/stgov/itrcindex.htm) was established in December, 1994 by the Develop On-Site Innovative Technology Committee, referred to as the DOIT Coordinating Group of the Western Governors Association. The Mission of the ITRC is to facilitate cooperation among states in the common effort to test, demonstrate, evaluate, verify and deploy innovative environmental technology, particularly technology related to waste management, site characterization and site cleanup. Western states participating include Arizona, California, Colorado, Idaho, Kansas, Nebraska, Nevada, New Mexico, Oregon, South Dakota, Texas, Utah and Washington. Other states that have joined or

have sent observers include Delaware, Florida, Illinois, Kentucky, Louisiana, Massachusetts, New Jersey, New York, Ohio, Pennsylvania, Tennessee, and Wisconsin, and the Southern States Energy Board has actively participated in the deliberations of the ITRC. In addition to the state members there are some representatives from stakeholder groups and tribal representation. Federal advisors have participated in the ITRC meetings from a number of Agencies including EPA (Technology Innovation Office), DOD, DOE and some of the armed services organizations.

The ITRC is organized into three task forces and technology specific task groups. Task forces have been established for Electronic Communication Development, Case Studies, and Protocols and Regulatory Requirements. The Protocols and Regulatory Requirements Task Force has established task groups to address specific technologies in the areas of *in situ* bioremediation, Low-Temperature Thermal Desorption, Plasma Hearth Technology, and Real-time Field Measurement (site characterization and penetrometer system).

Appendix D
Preliminary Research Plan
Contaminated Sites - Ground Water

Contents

Preliminary Research Plan
Contaminated Sites - Ground Water

Introduction

As discussed in Chapter 2, a preliminary research plan was developed for each research topic area. The Preliminary Research Plan for Contaminated Sites - Ground Water describes each of the research activities which ORD would conduct from FY97 to FY00 in order to address the most important research needs for contaminated ground water resulting from uncontrolled waste releases. Major products are identified for each research activity. A summary table (Table D-1) at the end of the appendix lists these products and indicates the fiscal year in which each will be produced.

Most of the research activities described in this appendix are already well established, since ORD has been conducting research in this area for a number of years (cf. Appendix A for description of the previous ORD ground water issue plan). There are only a limited number of new starts or significant expansion to existing programs reflected in the proposed ground water research activities. Significant new activities are in the areas of mixtures toxicology and containment.

Proposed Research Activities

Hazard Assessment Research Activities

Three research activities are discussed in this section: 1) ecological risk assessment methodology, 2) human dose response models for mixtures, and 3) mixtures toxicology.

Hazard Assessment is comprised of two major activities-- hazard identification and dose-response assessment. In hazard identification, health scientists identify what adverse effects (endpoints) are associated with various contaminants by reviewing and conducting studies such as microbial bioassays, toxicologic tests of laboratory animals, and human epidemiologic studies. Health endpoints include cancer, neurological effects, and reproductive effects. A major issue in hazard identification is how best to extrapolate the results of animal studies to humans. If a particular contaminant causes an effect in animals, is it likely to cause that same effect in humans?
Dose-response assessments are designed to answer the question “What is the relationship between the amount of contaminant (dose) and the adverse effect (response)?” The major impediment presented to risk assessors in answering this question is that the dose-response curve can not be observed at the low doses typically found in environmental settings. As a result, scientists must extrapolate from the higher dose animal studies to lower dose environmental situations. These extrapolations are a source of much scientific uncertainty and controversy in environmental risk assessment. Until recently, most extrapolations to low dose situations have focused

mainly on statistical “curve-fitting” methodologies. However, with major advancements in the science of cellar and subcellular biology during the past few year, scientists now have a much better understanding of specific mechanisms of action for many contaminants. Elaborate biological models are now being developed and tested that predict what happens to the contaminant after it comes into contact with the human receptor. These “physiologically-based toxicokinetic models” describe and predict the absorption, distribution, metabolism, and excretion of the contaminant. Further, “toxicodynamic models” describe the biological mechanisms of action of the contaminant at the actual location in the receptor where the toxic response occurs.

In addition to evaluating the effects for individual contaminants, research is needed to develop methodologies for assessing the combined toxicity of complex mixtures. Other that in the fields of carcinogenesis and mutagenesis, relatively little is known about the toxicity of these mixtures especially when multiple stressors are present.

Ecological Risk Assessment Methods

Current Research Activities
In FY97, there is no research being conducted in this research area in the Waste Research program. However, related research is addressed in other media programs and is described in the Ecological Risk Research Plan.

Future Research Activities
This research was identified as a possible area for future research. However, given its low ranking, this area is not likely to be funded under the waste research program. Most ecological risk assessment research will be conducted under the Contaminated Soils research topic.

Anticipated Major Products
- None planned.

Human-Dose Response Models for Mixtures

Current Research Activities
In FY97, research in this area will focus on updating the MIX-TOX data base. MIX-TOX contains summaries from the scientific literature describing the toxicological interaction of over 850 chemical in 1600 pairs. Work will begin by reviewing the toxicological literature since the last update (about 8 years ago) and incorporating those results into the data base.

Future Research Activities

Future activities will first focus on completing the update of the MIX-TOX data base and then focus on developing accompanying software and guidance. Additional research will also be undertaken to develop physiologically-based toxicokinetic models that will better predict the interaction of complex mixtures on mechanistic properties of the contaminants.

Anticipated Major Products

- Updated MIX-TOX data base describing the interaction of common mixtures; This data base summarizes published scientific literature describing the toxicologic interactions of over 850 contaminants in over 1600 pairs of contaminants. (98)

- Physiologically-based toxicokinetic models for solvents; These more biologically sophisticated dose-response models will evaluate the likelihood of toxic effects based on estimates of the delivered dose at the site of action in the target organ. These models should eliminate much of the current uncertainty in simpler dose-response models. (97/98)

- Benchmark dose models for noncancer endpoints; Toxicity values for noncancer endpoints (e.g., reference doses and reference concentrations) will be derived using the benchmark dose (BMD) methodology where data are available. This methodology is generally preferred to the traditional method of using no observed adverse effect levels (NOAELs) because it incorporates more information from the observable range of the dose-response curve. (98)

- Methods to evaluate the toxicity of complex mixtures; data on the biological mechanisms of action will be used to determine if various contaminants affect the same target organ in the same or dissimilar modes of action. Such mechanistic data will be evaluated whether the interaction of contaminants is additive, antagonistic, or synergistic. (99)

Mixtures Toxicology - Ground Water

Currently, we follow procedures in two guidelines for assessing the risks of health effects to humans from multiple chemicals in contaminated ground water: the Agency Guidelines for Health Risk Assessment for Chemical Mixtures (USEPA, 1986) and the Risk Assessment Guidance for Superfund (USEPA, 1989). These guidelines suggest that the best information is obtained from studies performed directly on the mixture of interest. Unfortunately, because the number of potential mixtures is virtually infinite and because few complete mixtures have been tested, the guidelines also recommend procedures with fewer constraints but more assumptions and uncertainty. For example, when no quantitative information on toxicologic interactions is available, the guidelines recommend applying dose addition to those component chemicals affecting the same

target organs, and they recommend making separate assessments for each target organ. Other assumptions include the independence of action at low doses for carcinogens and appropriateness of short-term and *in vitro* studies for assigning relative potency factors to chemicals in the same chemical class (e.g., dibenzo-dioxins and dibenzo-furans). The Agency guidelines are currently under revision by a Technical Panel of the Risk Assessment Forum. One proposed procedure is to use information on pair wise interactions to adequately characterize all the interactions in the complex mixture.

Current Research Activities
There is no research currently being funded by the Waste Research Program.

Future Research
Laboratory research is needed to evaluate the assumptions of the chemical mixtures risk assessment guidelines. In the event resources become available, future research will focus on evaluating the additivity assumption for classes of agents frequently found in ground water, and will include studies of biological mechanisms by which those agents in a mixture might produce antagonistic, additive, or synergistic effects. Research also will be undertaken to develop strategies for testing whole mixtures for toxicity and to improve quantitative methods for meta-analysis of existing studies. Decisions about the particular agents and mixtures will be made based upon (1) specific hypotheses on the biological mechanisms by which agents produce their effects and by which they may interact; (2) the frequency that those agents are found in contaminated ground water; and (3) the potential for exposure from those agents.

Anticipated Major Products
None are currently anticipated due to lack of funding. However, if funds were to become available, the following product is expected:

- Document evaluating constraints upon the additivity assumption for mixtures of an important class of ground water contaminants (FY2000+)

Exposure Assessment Research Activities

Ground Water Transport and Fate Modeling
EPA makes extensive use of models of subsurface contaminant transport and fate models to support decisions about regulatory actions to assess and manage risk. While the models that are available to the Agency have significantly improved in quality during the past ten years, they are still highly simplified representations of the real world and further improvements are needed if they are to realize their full potential. The objective of research on ground-water transport and fate modeling is to improve the quality of the models that are available to the Agency by (1) conducting research to better understand environmentally important subsurface processes, (2) incorporating

this process knowledge into a holistic understanding of subsurface phenomena, (3) developing and testing computer codes that quantitatively describe subsurface fluid and contaminant movement, and (4) applying these codes to assess the risk posed by subsurface contaminant plumes and to plan and implement remedial activities, and to estimate the risks posed by treatment residuals. Research on improving the quality of the models is closely linked to research to develop cost-effective site characterization methods to provide the necessary data for the models and to ensure that the models that are developed will not be limited by unrealistic data requirements which nullify their potential advantages.

Current Research Activities

Current work is extending earlier work on flow and transport in porous media to include situations with more complex hydrogeology and with multiphase fluid systems. Work is continuing to understand and model flow and transport in fractured carbonate rock which involves the coupling of flow and transport processes in the porous rock matrix with flow and transport through the fractures. This work extends previous research on flow and transport in fractured crystalline rock where the flow is only through the fractures. Work also continues on inverse solution methods for characterizing subsurface environments.

Future Research Activities

Future work will continue to stress useful practical extensions of current modeling capabilities by coordinating model development with ongoing field work in aquifer remediation and by continuing interaction with program offices in developing and evaluating models for predicting contaminant behavior when minimal data are likely to be available. Two areas of emphasis will continue to be fractured rock, including karst terranes, and multiphase fluid systems.

Anticipated Major Outputs

- Report on modeling alternatives for dealing with subsurface heterogeneity in ground water models used for national regulatory activity (98)

- Report on characterization and modeling of a fractured carbonate aquifer (99)

Ground Water Exposure Factors and Pathways

Current Research Activities

In FY97, research will be continued on developing models that estimate exposure from non-ingestion uses of water (showering, bathing, appliances such as dishwashers, washing machines, and humidifiers). In addition, research will also be initiated to develop statistical distributions for several important factors related to exposure to ground water contaminants.

Future Research Activities
Future activities will focus on continuing to develop, peer review, and validate the above described exposure models and statistical distributions.

Anticipated Major Products
- Models that estimate exposure from non-ingestion uses of water (showering, bathing, appliances such as dishwashers, washing machines, and humidifiers). (97)

- Statistical distributions for several important factors related to exposure to ground water contaminants. Such factors are expected to include: showering time, breathing rates, and frequency of various activities that result in exposure. (98)

Risk Characterization Research Activities

Risk Characterization
Risk Characterization is the transition between risk assessment and risk management. There are three main objectives to the risk characterization process: (1) integrate the results of other parts of the assessment, (2) evaluate the strengths and weaknesses of the results and conclusions, and (3) communicate the results of the assessment to the risk managers, and stakeholders, including the community. The risk characterization should also check to ensure that the assessment is not racially or culturally biased (i.e., susceptible or socially disadvantaged subpopulations needs to be properly evaluated).

There was no risk characterization research planned under this research topic. Risk communication is addressed under the Human Health Risk Assessment Research Plan.

Remediation Research Activities

Natural Attenuation
Given the proper conditions, naturally occurring subsurface biotic processes will transform hazardous contaminants to a form in which they no longer present a threat to human health or the environment. As a result of these transformations, and the actions of abiotic and hydrologic processes, contaminant concentrations in a plume of contaminated ground water will be reduced or attenuated. This phenomenon of natural attenuation (NA) is important as both a ground-water remediation tool and for estimating risk as part of the development of waste management regulations. At some waste sites, natural attenuation (NA) may be the sole remedy, as long as there is careful evaluation to show its potential effectiveness, and monitoring of its progress.

More typically, NA may be appropriate for use as a component of the total remedy (e.g., in conjunction with active remediation) or as a follow-on to active remediation.

At the present time there are major uncertainties about how to best determine the applicability of natural attenuation as a remedial measure and to monitor its effectiveness. For natural attenuation to fully realize its potential as a remedial measure it is necessary to have (1) a better understanding of natural occurring biotic processes and subsurface microbial ecology, (2) reliable indicators to measure the rate and extent of natural attenuation, (3) improved knowledge of geochemical indicators of the potential for natural attenuation of contaminant plumes, and (4) user friendly models to integrate field and laboratory data to predict the likelihood of the successful implementation of natural attenuation as a remedial measure. Research on natural attenuation addresses these needs and is a critical part of ORD's efforts to provide reliable guidance on the selection and monitoring of natural attenuation for the Agency's waste management programs.

Current Research Activities

A major effort to develop and field evaluate protocols for the appropriate use of natural attenuation will continue. This effort also includes research to develop reliable indicators that can be used as tools to assess the effectiveness of natural attenuation of organic chemicals, particularly fuels and chlorinated solvents. Research on the use of natural attenuation for fuels will emphasize studies of the conditions under which MTBE will naturally degrade.

Future Research Activities

The emphasis on natural attenuation of chlorinated solvents will diminish as these protocols near completion. Work on natural attenuation of MTBE will probably continue into FY99 because of the basic lack of knowledge of the conditions under which it will naturally attenuate and the mixed results which have been obtained by research to date. The natural attenuation of metals (actually speciation, since metal do not degrade) will be an increasing emphasis of the research, as will natural attenuation of complex mixtures and landfill leachates. The research on the biodegradation aspects of natural attenuation will be coupled with studies of the role played by the hydrogeologic setting in risk management decisions based on natural attenuation.

Anticipated Major Products

- Revised protocol for natural attenuation of chlorinated solvents in ground water. (98)
- EPA report on Decision Support System for contaminants in the vadose zone (98)
- Revised protocol for natural attenuation of metals and inorganic compounds. (00)
- Revised protocol on site characterization for a risk based evaluation. (99)
- Report of Effect of Spacial Heterogeneity on the Natural Bioattenuation of Dissolved Hydrocarbons (External Grant) (00)

Bioremediation

The enhancement of the rate of bioremediation of contaminated ground water plumes and of NAPLs has the potential to be the most cost-effective cleanup option available for certain contaminants. Natural attenuation may be too slow to adequately reduce the risks of contaminants (e.g., NAPLs) that are more rapidly destroyed by enhanced biodegradation (i.e., "bioremediation"). The objective of bioremediation research is to identify and understand natural biodegradation processes that have the potential for being cost-effectively enhanced, and to determine the scientific and engineering approaches needed to develop these processes into viable full-scale techniques.

Current Research Activities

Research on subsurface bioremediation in FY97 will strongly emphasize the development and evaluation of a set of tools for reducing risk from subsurface contamination resulting from the improper use and disposal of chlorinated organic solvents. Work will continue on pilot-scale field evaluation of the use of stimulated *in-situ* anaerobic processes to degrade chlorinated organic solvents and on laboratory evaluation of the use of electrical stimulation of the reductive dechlorination of chlorinated solvents. Promising laboratory research on the use of *in-situ* biotic processes to degrade metallic contaminants such as chromium and uranium will continue as a prelude to probable field evaluation.

Future Research Activities

The need for further research to scale-up the evaluation of the use of stimulated anaerobic biotic processes to degrade chlorinated solvents will be based on the results of small-scale field tests being conducted by NRMRL and RTDF that will be completed in FY98. Current laboratory work on the use of direct electrical stimulation of reductive dechlorination as a possible reactive barrier technology will be evaluated at pilot scale in the field as will the use of biotic processes to degrade metallic contaminants. Research will also evaluate the potential for biotic processes to be used to address problems of source zones of nonaqueous phase liquids (NAPLs).

Anticipated Major Products

- Report on the use of enhanced *in situ* bioremediation processes for remediation of ground water contaminated by chemical solvents (98).

Abiotic Treatment

In situ abiotic subsurface processes also hold promise for remediating aquifer contamination. The use of abiotic processes is often complementary to the use of biotic processes, and at some sites, the use of both in a treatment train may be an optimal approach for remediation. There are two types of remediation problems addressed here. One is treatment of dissolved contaminants in ground water. This is important, since it reduces the amount of contaminants which are transported to humans or ecosystems. Remediation of NAPLs that are present in the subsurface is important because they may act as sources of soil and ground-water contamination for long periods of time, unless they can be removed or contained. Both NAPLs that are less dense than water (LNAPLs) and those that are more dense than water (DNAPLs) are widespread subsurface contamination problems due to their ubiquitous, high-volume use and past waste-disposal practices. DNAPLs represent one of the greatest impediments to successful cleanup of a large fraction of Superfund sites.

Currently, there are few remediation technologies that effectively address either dissolved contaminants or pools of undissolved contaminants. In many cases pump-and-treat can contain (or even reduce the extent of) a contamination plume, but it is expensive because of the long time (typically decades) for which it must be applied. In many other cases, the cost of pumping to contain the plume is prohibitive. Commercially available extraction technologies for the treatment of the dissolved ground water contamination that rely on the movement of air rather than water, such as air sparging or soil vacuum extraction are generally less costly than pump and treat because of the lower costs associated with pumping air as compared with the cost of pumping water. However, there are many sites where such technologies cannot be effectively applied, and they suffer from many of the same problems as pump and treat. Some success in LNAPL remediation has been achieved using direct pumping or soil venting but currently, there are no rigorously evaluated technologies for treating DNAPLs that are too deep to excavate.

The abiotic treatment research activities are investigating the use of *in situ* permeable reactive barriers (PRBs), or treatment zones, for contaminated ground water. Extraction is the principal means of NAPL treatment being studied, although chemical and biological treatment options will also be evaluated.

The objective of the abiotic remediation research to evaluate innovative subsurface remedial technologies is to increase the options for risk managers dealing with sites containing contaminated soil and ground water. The emphasis of the research

includes: (1) evaluating enhanced-extraction technologies for subsurface NAPL contamination, particularly DNAPLs, (2) evaluating techniques for remediating plumes composed of a mixture of metals, chlorinated solvents and other dissolved organic contaminants, and (3) evaluating subsurface site-characterization technologies to improve the quality of the evaluation of remedial technologies, (4) developing, evaluating, and applying models to better design and evaluate subsurface remedial technologies, (5) developing design and implementation cost information for the decision making process and (6) conducting the necessary process-level research required to improve the quality and effectiveness of subsurface remediation.

Current Research Activities

Data analysis for a field pilot-scale side-by-side evaluation of nine extraction technologies for a complex LNAPL waste at Hill AFB, Utah will be completed in FY97. The most successful of these technologies involves the injection of a chemical additive, such as an alcohol cosolvent or a surfactant, to increase the solubility or mobilize the NAPL. A similar study, to evaluate these technologies for DNAPLs, is being initiated at the DoD National Test Facility at Dover AFB, Delaware. The test at the second site will determine the extent to which the technologies which proved successful in extracting residual LNAPL contamination are effective against DNAPLs. It will also provide information on the use of these extraction technologies in a different hydro geological setting. In-house laboratory studies of the use of hot water to enhance the extraction of viscous oils from the subsurface will be evaluated for possible field application.

Permeable reactive barriers are being investigated in parallel laboratory field studies as a possible remedial measure for a variety of organic and inorganic ground water contaminants. Laboratory studies are investigating the possible ways that the material making up the barrier could be modified to deal with many different chemical contaminants. For example, it has been suggested that peat or other high organic materials could be used to immobilize organic contaminants. Reactive barriers also offer a possible means of stimulating subsurface biological reactions to transform or destroy toxic chemicals. A full-scale field study of PRB applicability to ground water contaminated by a mixture of hexavalent chrome (Cr(VI)) and trichloroethane (TCE) is underway at the U.S. Coast Guard facility at Elizabeth City, North Carolina. Documents for waste site managers describing the applicability of PRB technology are in preparation.

Future Research Activities

Field work on the pilot-scale evaluation of DNAPL extraction technologies should be completed in FY98 and a report on the comparison of the technologies should be available in FY99. Preliminary reports on individual technologies will begin to become available in FY98. For the most promising of these technologies to reach the state where they can be routinely used for site cleanups or containment, additional

evaluation will need to be conducted in different hydro geologic settings and at larger scale. These evaluation will need to be coupled with research to develop better techniques to locate and characterize DNAPL contamination, models to understand and plan the application of remedial technologies for DNAPL contamination, and process-level research to better understand and predict the subsurface behavior of DNAPLs. Along with research to improve the effectiveness of these technologies, there is a need for parallel research to develop tools to measure their cost effectiveness and their potential for commercial application.

For PRB technology to reach its full potential, it will be necessary to evaluate it for additional applications under a variety of hydro geologic and geochemical conditions. Additional work is also needed to develop more efficient and cost-effective methods to evaluate the performance of PRBs, to emplace the barrier materials at greater depths in the subsurface, and to improve the reactive materials and mixtures to increase the transformation/degradation kinetics and the barrier lifetime. Much of the work to date has been empirical in nature and there is a need to improve the fundamental understanding of the reactions that take place within the barrier to enable barrier design to move to a reliable engineering technology.

Anticipated Major Products

- Summary report on the side-by-side comparison of nine NAPL extraction technologies at Hill AFB, Utah (98)
- Preliminary guide on the use of permeable reactive barriers (98)
- Report on the fate and persistence of residual surfactants (98)
- Summary report on the side-by-side comparison of DNAPL extraction technologies at Dover AFT, Delaware (00)
- Report on a Multi-Scale Investigation of Mass Transfer Limitations in Sufactant-Enhanced Aquifer Remediation (External Grant) (00).
- Report on Investigation of Entrapment and Surfactant Enhanced Recovery of NAPLs in Heterogeneous Media (External Grant) (00).

Containment

At many Superfund and other sites where waste was improperly disposed, physical and hydraulic containment systems are in use, often as part of a phased approach to remediation. For example, at sites with DNAPL source zones, containment may be recommended as a means of preventing further contamination of adjacent ground water, allowing pump-and-treat, natural attenuation, or some other remedy to be used with a high probability of success to cleanup the dissolved plume. The remedy might also include a provision for cleanup of the source area at a future time when a cost-effective solution is available.

Hydraulic containment relies on the use of wells to confine the contaminated ground water to a specific location or prevent it from moving beyond a specific point, such as a plant boundary. Engineered containment relies on the use of a constructed impermeable vertical barriers keyed into an impermeable geologic layer to confine the contamination. An engineered containment structure often includes some sort of hydraulic control to ensure that the hydraulic gradient is into the confined zone. Containment is most frequently used as a short- to mid-range solution until such time as technology for providing a more permanent solution is available. In other cases, containment is used to confine a ground-water contamination problem to allow more efficient operation of an engineered treatment system such as bioremediation. Because of their high operating costs, hydraulic containment systems are largely regarded as short-term solutions.

Despite the increasing use of engineered containment structures as a remedial option, there are a number of unanswered questions about their long-term reliability coupled with a lack of reliable means for monitoring the stability of the containment system. Until the early 1990's, most hazardous waste containment systems were designed and constructed based on engineering practices used to control ground water seepage in the construction industry. While moderate rates of leakage may be acceptable for construction dewatering operations, requirements to minimize leakage of any sort from a hazard waste containment system are much more stringent.

The objective of the research is to develop and evaluate methods for determining and improving the long-term reliability of engineered containment systems that are designed to confine subsurface contamination as part of a remedial action. Areas of research may include: (1) early warning methods to determine structural changes in the barrier over time; (2) methods to detect the location and rate of leakage from the barrier in conjunction with techniques for repairing the leak; (3) evaluation of the compatibility of common DNAPLs with widely used barrier materials; (4) evaluation of the long-term reliability of engineered barriers; and (5) the development and evaluation of “dual-barriers” in which an impermeable engineered barrier would be combined with a permeable reactive barrier.

Current Research Activities

This area is currently unfunded although a small amount of related work is being conducted as part of the Laboratory’s technical support activities and in conjunction with research on the development and evaluation of permeable reactive barriers.

Future Research Activities

New research, pending availability of funds, is proposed in the following area: (1) evaluating methods to detect the location and size of leaks from the barrier by evaluating the three dimensional hydraulic signature associated with a window (leak) in

a subsurface vertical barrier and determining the minimum number of monitoring points necessary to identify containment-system leaks under various hydrogeologic conditions; (2) evaluating the compatibility of common DNAPLs, such as PCE or TCE, and widely used barrier materials; (3) evaluation of the chemical and geochemical changes that take place when the waste is enclosed by an impermeable vertical barrier, an impermeable geologic layer on the bottom, and an impermeable cap to prevent infiltration; (4) evaluating the long-term performance of engineered containment structures; and (5) the development and evaluation of “dual-barriers” which combine the technology of permeable reactive barriers with the technology of impermeable barriers to provide a backup system should the impermeable barrier leak.

Anticipated Major Products
This would be a new area of research and therefore it is difficult to list specific outputs. Outputs are expected to be technical reports, tech transfer documents, and workshops to transfer the results of the research to the Agency’s operating programs.

Demonstration and Verification of Innovative Remediation Technologies
Demonstration and verification of innovative ground water remediation technologies is conducted as part of the ORD Superfund Innovative Technology Evaluation (SITE) program. The program is described in detail in the subsection "Demonstration and Verification of Innovative Soil/Vadose Zone Remediation Technologies" later in Appendix E.

Current Research Activities
Evaluations are being conducted on a number of ground water remediation technologies, including both in situ and pump-and-treat. Major anticipated outputs for FY97 are listed below. Other outputs generic to the SITE Program are described in Appendix E.

Future Research Activities
Ground water remediation technologies are currently a focus area for the SITE program and are expected to remain so through FY00 because of the lack of cost-effective ground water remediation technologies and the need for more cost-effective containment techniques. Technology transfer documents describing the results of individual technology evaluations and comparative evaluations of technologies of a particular type or applicable to a particular contamination problem will be the major outputs of the SITE program.

Anticipated Major Products
- Spray Irrigation Treatment System Capsule Report and Innovative Technology Evaluation Report (ITER) (97).
- CURE Metals Treatment ITER (97).

- Enviro Metal Technologies, Inc. Halogenated Organic Compound Treatment System Capsule Report and ITER (97).

Monitoring Research Activities

Subsurface Characterization Research Activities
Delineating, characterizing, and sampling contaminants and contaminant plumes in the subsurface/ground water environment continues to be one of the most complex, difficult, and costly aspects of Superfund and Hazardous Waste site characterizations. Determining contaminant location and movement in the subsurface requires that we not only detect and quantify the pollutant of interest, but that we also understand and measure the inherent subsurface hydrogeological and geochemical structure and properties that influence or control the contaminants spatial and temporal distribution. To address these challenges, the focus of our research is on the development and evaluation of surface-based, non-invasive, geophysical technologies. Several geophysical technologies are currently in wide use, for example, magnetometers and a variety of resistivity measurement devices, but their use is often limited by their ability to characterize plumes at depth and by other environmental factors like soil moisture content and cultural interferences (e.g., buried pipelines).

Current of Research Activities
The major subsurface characterization issue being addressed now, and for the foreseeable future, is the detection and quantification of dense and light, non-aqueous phase liquids (DNAPLs and LNAPLs). This kind of contaminant is often associated with leaking underground storage tanks (petroleum products) or solvent usage (chlorinated solvents) commonly found at Superfund sites and Hazardous Waste disposal facilities and is particularly troublesome since they "sink" (dense NAPLs) through the aquifer or "float" (light NAPLs) on the top of the ground water table, or is distributed in "pockets" throughout the subsurface.

To address the need to find ways to detect these contaminants and characterize the hydrogeologic environments in which they are found, a unique controlled spill facility will be built in partnership with other Federal Agencies. This facility will be constructed with non-metallic reinforcement to allow the use of electrical and magnetic geophysical methods without the interference of metal liners or reinforcing rods. The facility will also allow us to construct aquifers with our own hydrogeologic parameters, so we can study the effects that different materials, such as sand vs clay, have on the measurement technique being studied. The initial experiment in this facility will look at detection methods for a dense chlorinated solvent.

Future Research Activities

Future progress in subsurface characterization is especially important to fully understand the site remedies that are increasingly being selected, which are natural attenuation and containment. In this type of remedy, which differs from an active removal of contaminant mass, it is very important to have an adequate site characterization performed and monitoring system installed. Research will be conducted in the field facility to meet these needs, and will include experiments to find methods to monitor natural attenuation. Other experiments to monitor the effectiveness of containment barriers will be performed, along with experiments that will increase the efficiency and accuracy of monitoring systems. This research would include sampling device comparisons, monitoring well design evaluations, sensor evaluations, and monitoring network design methods.

Anticipated Major Products

- ASTM Standards for Ground Water Monitoring and Environmental Characterization (97).
- Evaluation of Non-Invasive, Cost-Effective Geophysical Techniques (Ground Penetrating Radar) to Delineate Subsurface, Light Non-Aqueous Phase Liquids (LNAPLs) in a Controlled Gasoline Spill Experiment (98)
- Evaluation of Non-Invasive, Cost-Effective Geophysical Techniques (Electrical Resistivity Tomography) to Delineate Subsurface, Light Non-Aqueous Phase Liquids (LNAPLs) in a Controlled Gasoline Spill Experiment (98)
- Partitioning Tracers for *In situ* Detection and Measurement of Nonaqueous Phase Liquids in Porous Media (External Grant) (99)

Field and Screening Analytical Methods for Ground Water

One of the approaches for reducing uncertainties in the assessment of human exposure is to better characterize the hazardous wastes which contaminate our environment. A limitation to this is that we must be certain that our analytical methods can detect the compounds of concern and at levels that are toxicologically important. This often requires us to develop more specific and sensitive analytical methods. Another significant limitation is that sampling and laboratory analysis of contaminated water/ground water is slow and expensive; thus, limiting the number of samples which can be analyzed within time and budget constraints. In cases where a limited number of target analytes can be identified, faster and more cost-effective field screening and monitoring methods can potentially increase the amount of information available concerning the location and concentration of pollutants which may impact human health and the environment.

Current Research Activities

Among field analytical techniques, methods which rely on biomolecular recognition show the potential for sensitive, specific, fast, and cost-effective analyses. Many of these methods have been demonstrated for environmental field applications. Field

screening methods include immunoassays and biosensors based on antibodies and enzymes. Laboratory-based quantitative immunoassays can support in-depth site characterization and exposure assessment studies.

Research in the application of advanced instrumentation to water/ground water characterization focuses on methods that will provide high-quality data rapidly with simple and rugged protocols. Emphasis is on technologies that can eventually be used to perform analysis in the field, those that can determine pollutants that are intractable by conventional EPA methods, as well as those that improve risk assessments by providing specific information on the most hazardous forms of pollutants. Specific areas of investigation in FY 97 include gas chromatography/atomic emission detection (AED) as a simple, reliable and potentially field portable technique for measuring organic pollutants containing heteroatoms (e.g., pesticides); capillary electrophoresis (CE) for very rapid analysis; the combination of CE with laser-induced fluorescence (LIF) detection for potentially field-portable analysis; and elemental speciation methods for measuring concentrations of the most hazardous forms of inorganic pollutants.

Future Research Activities

Research will continue in several areas including the development, characterization and verification of immunoassay and biosensor methods for field screening and monitoring applications related to ground water.

Areas which are particularly promising with respect to biosensor research include the investigation of biosensor techniques for environmental applications which require: continuous and *in situ* assay formats; operation in undiluted, turbid, colored, fluorescent, or organic matrices; and multi-component screening capabilities. Compound classes which will be investigated include: NAPLs, indicators of natural attenuation, pesticides, explosives, PAHs, and phenolic compounds.

The teaming of immunochemical methods with instrumental analysis will continue to be developed. Super critical fluid extraction (SFE) coupled with immunoassays can provide methods that are highly quantitative. Immunoaffinity chromatography sample preparations can streamline sample preparations for mass spectrometry. These hyphenated techniques exploit the advantages of two different technologies and provide powerful analytical capabilities. Multi-analyte immunoassay formats will be investigated for field applications. The development of methods to support toxicological and pharmacological studies will also continue.

Research in waste monitoring technologies based on advanced instrumentation will be influenced by several developments in site characterization.

- Inexpensive “punch” type sampling of ground water is often preferred over monitoring from permanent wells. Analytical methods appropriate for the large number of low-volume samples produced by this sampling approach must be developed. Capillary electrophoresis should be well suited for such applications.
- The trend toward field methods will continue. Once laboratory CE methods are developed and demonstrated, the technology should be well suited for field use. Very rapid, field-portable sample preparation technologies will also be developed.
- Natural attenuation as a remedial option is becoming accepted. Monitoring methods for initial site characterization and for assessing the efficacy/ performance of this approach must be made available.
- More sophisticated estimates of risk based on element speciation information are allowing the increased use of alternative remedial goals. The speciation methods for a number of pollutants in multiple media must be developed and evaluated.

Anticipated Major Products

- Biosensors for Environmental Monitoring (97/98)
  - KinExA Method for Screening 2,4-D
  - Phosphotriesterase-based Biosensor for Detection of Organophosphates
- Immunochemical Methods for Environmental Monitoring (97/98)
  - Quality Assurance Guidelines for Evaluating Immunoassay Methods for Environmental Analysis
  - SITE Evaluation of Field Portable Immunoassay Technologies
  - Field Evaluation of an Immunoassay and a Stripping Voltammetry Method to Determine Mercury
- Enzyme-electrode Biosensor for Screening of Phenolic Compounds at Superfund Sites (97/98)
  - Improved Tyrosinase-based Carbon Paste Phenol Biosensor
- Improved Pentachlorophenol Immunoassay (97/98)
- Methods for the Speciation of Inorganics in Environmental Samples (97)
- Development of Chemical Methods to Assess the Bioavailability of Arsenic in Contaminated Media (External Grant) (99)
- Bioavailability and Risk Assessment of Complex Mixtures (External Grant) (99)

Demonstration and Verification of Field Monitoring and Characterization Technologies

Current Research Activities

Rapid, reliable and cost effective field screening technologies are needed to assist in the complex task of characterizing and monitoring of hazardous and chemical waste sites. However, some environmental regulators and remediation site managers may be reluctant to use new site characterization technologies that have not been validated in an EPA-sanctioned testing program, since data from them may not be admissible in potential legal proceedings associated with a site or its cleanup. Until characterization technology claims can be verified through a scientifically sound, unbiased evaluation, the user community will remain skeptical of innovative technologies, despite their promise of better, less expensive and faster environmental analyses.

A program of monitoring technology verification has been implemented through the Consortium for Site Characterization Technology (CSCT) which is funded by the Superfund Innovative Technology Evaluation (SITE) program, the Environmental Technology Verification ETV program (part of the President's Environmental Technology Initiative (ETI), and the Department of Defense's Strategic Environmental Research and Development Program (SERDP). In addition, it is partnered with a number of other Federal, State, and private organizations, including the Department of Energy's technology demonstration programs.

The goal of the verification program is to identify, demonstrate, assess, and disseminate information about innovative and alternative environmental monitoring, measurement, and characterization technologies to developers, remediation site managers, and regulators. This is intended to be a principal source of information and support with respect to the availability, maturity, and performance of these technologies. The technology demonstration process clearly defines the performance assessment, evaluation, and verification pathway and includes the following components: technology selection, technology performance assessment, evaluation, and verification, and information distribution/dissemination via innovative technology verification reports.

Future Research Activities

The characterization and monitoring technology verification program will find many ready candidates for demonstration over the next few years. Researchers within and outside the government are developing new techniques and optimizing and miniaturizing existing technologies. The technology pipeline includes technologies ranging in maturity from first generation prototypes to commercially available. Some of the technologies on the demonstration horizon include a vast array of remote sensing techniques, miniaturized laboratory instrumentation, and geophysical methods. Some of the less mature technologies include surface acoustic wave devices for monitoring contaminants in water, air and soil gas; innovative geophysical techniques; new

sensors for deployment by cone penetrometers; and ultrasonic sensors for *in situ* monitoring of physical properties.

Anticipated Major Products
The Innovative Technology Verification Reports (ITVR) are produced from each technology demonstration and document the performance of technologies that have participated in the verification program.

- Reports anticipated from the cone penetrometer demonstration are:
  - Site Characterization Analysis Penetrometer System Laser-Induced Fluorescence (LIF) Sensor and Support System.
  - Rapid Optical Screening Tool (ROST) Laser-Induced Fluorescence (LIF) system for screening of Petroleum Hydrocarbons in Subsurface Soils.

- Reports from planned demonstrations, which are:
  - Demonstration of *In situ* Analyzers
  - Demonstration of PCB Analysis Methods for Water, Soils and Sediments

Summary Tables
The ground water research plan summary sheet (Table D-1) lists the major products that ORD anticipates it will generate as a result of each ground water research activity. The table shows the fiscal year (FY) in which the product is projected to be generated, and indicates whether the work is currently funded or unfunded. A plus mark ("+") means that the product would be funded under the current allocation of ORD research funds. A minus mark ("-") indicates that funding is not currently allocated to this product. A product is considered "currently funded" if there would be adequate funds to develop and complete it under the proposed FY98 President's Budget and FY99 and FY00 budgets that are the same as the proposed FY98 President's Budget.

References

USEPA. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures.* Federal Register, vol. 51, no. 185, September 24, 1986.

USEPA. 1989. *Risk Assessment Guidance for Superfund* (Vol. 1. Human Health Evaluation Manual, and Vol. 2. Environmental Evaluation Manual). US Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. 1989.

Table D-1. Waste Research Plan Summary Sheet - Contaminated Ground Water
("+" = planned, funded product; "-" = anticipated, unfunded product)

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Hazard Assessment	Mixtures Toxicology			.....	
	-Document evaluating constraints upon the additivity assumption				-
	Human Dose-Response Models for Mixtures	.....			
	- Update MIX-TOX Database Describing the Interactions of Common Mixtures		+		
	- Physiologically-based Toxicokinetic Models for Solvents	+			
	- Benchmark Dose Models for Noncancer Endpoints				
	- Methods to Evaluate the Toxicity of Complex Mixtures		+		
				+	
	Ecological Risk Assessment Methods			.....	
	- None planned				
Exposure Assessment	Environmental Fate and Transport Modeling	.....			
	- Report on Modeling Alternatives for Dealing with Subsurface Heterogeneity		+		
	- Report on Characterization and Modeling of a Fractured Carbonate Aquifer			+	
	Ground Water Exposure Factors, Pathways	.....			
	- Models that Estimate Exposure from Non-ingestion Uses of Water	+			
	- Statistical Distributions for Several Important Factors Related to Exposure to Ground Water Contaminants		+		

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Risk Characterization	None				
Control	None				
Remediation	Natural Attenuation	.....			
	- Revised Protocol for Natural Attenuation of Chlorinated Solvents in Ground Water		+		
	- Report on Decision Support System for Contaminants in the Vadose Zone		+		
	- Revised Protocol for Natural Attenuation of Metals and Inorganic Compounds				+
	- Revised Protocol on Site Characterization for a Risk-based Evaluation			+	
	- Report on Effect of Spatial Heterogeneity on the Natural Bioattenuation of Dissolved Hydrocarbons (External Grants)				+
	Bioremediation	.....			
	- Report on the Use of Enhanced *In situ* Bioremediation Processes for Remediation of Ground Water Contaminated by Chemical Solvents		+		

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Abiotic Treatment	.....			
	- Summary Report on the Side-by-Side Comparison of Nine NAPL Extraction Technologies		+		
	- Summary Report on the Side-by-Side Comparison of DNAPL Extraction Technologies				+
	- Preliminary Guidance on the Use of Permeable Reactive Barriers		+		
	- Report of the Fate and Persistence of Residual Surfactants		+		
	- Report on A Multi-Scale Investigation of Mass Transfer Limitations in Surfactant-Enhanced Aquifer Remediation (External Grant				+
	- Report on Investigation of the Entrapment and Surfactant Enhanced Recovery of NAPLs in Heterogeneous Sandy Media (External Grant)				+

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Containment - to be determined	.....			
	Remediation Technology Demonstration (SITE) -See also discussion under Soils/Vadose Zone in Appendix E.	.....			
	- Spray Irrigation Treatment System Capsule Report and Innovative Technology Evaluation Report (ITER) (97)	+			
	- CURE Metals Treatment ITER (97)	+			
	- Enviro Metal Technologies, Inc. Halogenated Organic Compound Treatment System Capsule Report and ITER (97)	+			

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Monitoring	Subsurface Characterization	.....			
	- ASTM Standards for Ground Water Monitoring and Environmental Characterization	+			
	-Evaluation of Non-invasive, Cost-effective Geophysical Techniques to Delineate Subsurface LNAPLs - Ground Penetrating Radar		+		
	- Evaluation of Non-invasive, Cost-effective Geophysical Techniques to Delineate Subsurface LNAPLs - Electrical Resistivity Tomography		+		
	- Partitioning Tracers for *In situ* Detection and Measurement of NAPLs in Porous Media (External Grant)			+	
	Field and Screening Analytical Methods - Ground Water	.....			
	- Quality Assurance Guidelines for Evaluating Immunoassay Methods for Environmental Analysis (also see the discussion under Soils/Vadose Zone in Appendix E)		+		
	- Development of Chemical Methods to Assess the Bioavailability of Arsenic in Contaminated Media (External Grant)			+	
	- Bioavailability and Risk Assessment of Complex Mixtures (External Grant)			+	

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Demonstration / Verification of Field Monitoring Technologies -Site Characterization Analysis Penetrometer System Laser-Induced Fluorescence Sensor and Support System - Rapid Optical Screening Tool (ROST) Laser-Induced Fluorescence System for Screening Petroleum Hydrocarbons in the Subsurface (also see the discussion under Soils/Vadose Zone in Appendix E)	..... + +			

Appendix E
Preliminary Research Pan
Contaminated Sites - Soils/Vadose Zone

Contents

Preliminary Research Pan

Contaminated Sites - Soils/Vadose Zone

Introduction

As discussed in Chapter 2, a preliminary research plan was developed for each research topic area. The Preliminary Research Plan for Contaminated Sites - Soils describes each of the research activities which ORD would conduct from FY97 to FY00 in order to address the most important research needs for contaminated soils and the vadose zone resulting from uncontrolled waste releases. Major products are identified for each research activity. A summary table (Table E-1) at the end of the appendix lists these products and indicates the fiscal year in which each will be produced.

Most of the research activities described in this appendix are already well established, since ORD has been conducting research in this area for a number of years (cf. Appendix A for description of the previous ORD surface cleanup and bioremediation issue plans). There are only a limited number of new starts or significant expansion to existing programs reflected in the proposed soils/vadose zone research activities. Significant new activities are in the areas of mixtures toxicology and wild life species risk assessment.

Proposed Research Activities

Hazard Assessment Research Activities

Ecological Screening Tests to Measure the Effectiveness of Treatment

An important issue for site remediation is deciding on soil/vadose zone cleanup goals. This is dependent upon determine what levels of residual contaminant pose acceptably low risks to humans and ecosystems. One approach is to develop contaminant-specific models which allow one to estimate the pathways and rates for transport of the contaminant into the organism (e.g., its bioavailability), as well as the degree to which contaminants are toxic to the organ in the organism. Back calculations using these models then allow one to set risk-based cleanup goals. Research required to implement this approach requires 1) understanding the bioavailability of contaminants adsorbed onto soil particles, and 2) the use of physiologically-based pharmacokinetics (PBPK) and biologically-based dose/response modeling. Other ORD research programs are providing the PBPK and dose/response models (and structural activity relationships, if needed) needed for this approach. Required research on the bioavailability of contaminants in soil would be conducted as part of the research activity Estimating Human Exposure and Delivered Dose for Contaminated Soils which is discussed later in this subsection.

An alternative approach to estimating the risk of contaminants in soils to receptors uses indicator specifies as substitutes for detailed transport and impacts modeling. This second approach would allow one to screen residual contamination as a site in a tiered approach (with increasing rigor of testing), with the first, screening-level tests indicating whether further detailed modeling (such as utilized in the first approach) is necessary. Detailed modeling would be unnecessary if screening tests indicated that there was a high probability that the residuals would not pose a significant risk. Such a tiered approach to determining risk-based cleanup goals would save significant time and money.

Current Research Activities

ORD is assessing the usefulness of the earthworm toxicity, seed germination and root elongation assays for evaluating the eco toxicity of PAH contaminated soil. (Development of a simulated gastrointestinal tract will begin as a means of improving the accuracy of estimates of bioavailability of contaminants to humans.) Also, a study will be initiated to relate the results of microbial community analysis - *via* fatty acid methyl esters (FAME) test - to soil toxicity at contaminated sites in order to determine if the FAME test can be used as a residual risk screening technique.

Future Research Activities

Research in the out years will largely involve continuation and completion of research activities that are underway. It is anticipated that there will be a need to expand work on the evaluation of ecosystem assays. Once appropriate assays are developed for PAHs, work will turn to the evaluation of assays for residuals containing metals, pesticides and PCBs.

Anticipated Major Products

- Technical resource document on assays applicable to PAHs in soils (99).
- Preliminary report on the correlation of FAME tests with soil toxicity (98).
- Technical resource document on the applicability of FAME tests for screening soil toxicity (01).
- Prototype reactor simulating complete gastrointestinal system (01).

Mixtures Toxicology - Soils

Currently, we follow procedures in two guidelines for assessing the risks from exposure to multiple chemicals in contaminated soils: the Agency Guidelines for Health Risk Assessment for Chemical Mixtures (USEPA, 1986) and the Risk Assessment Guidance for Superfund (USEPA, 1989). A discussion of these guidelines can be found in the Mixtures Toxicology Research Activity described in Appendix D.

Current Research Activities

There is no research currently being funded by the Waste Research Program.

Future Research
Laboratory research is needed to evaluate the assumptions of the chemical mixtures risk assessment guidelines. In the event resources become available, future research will focus on evaluating the additivity assumption for classes of agents frequently found in contaminated soils, and will include studies of biological mechanisms by which those agents in a mixture might produce antagonistic, additive, or synergistic effects. Research also is needed to develop strategies for testing whole mixtures for toxicity and to improve quantitative methods for meta-analysis of existing studies. Finally, research is needed to predict the most toxic chemical byproducts produced by the degradation of soil contaminants, such as pesticide mixtures. Decisions about the particular agents and mixtures will be made based upon (1) specific hypotheses on the biological mechanisms by which agents produce their effects and by which they may interact; (2) the frequency that those agents are found in contaminated soil; and (3) the potential for exposure from those agents.

Anticipated Major Products
None are currently anticipated due to lack of funding. However, if funds were to become available, the following product is expected:

- Document evaluating constraints upon the additivity assumption for mixtures of an important class of soil contaminants.

Exposure Assessment Research Activities

Estimating Human Exposure and Delivered Dose

Current Research Activities
This research area addresses several issues that are very important to risk assessors because they are highly uncertain, controversial, and tend to drive site cleanup decisions: soil ingestion rates, activities affecting human contact with soil, dermal absorption rates, bioavailability of contaminants, and how to evaluate the inherent variability and uncertainty of exposure factors.

Future Research Activities
Future research is expected to continue to emphasize development of exposure models, factors, and methodologies that provide more realistic estimates of exposure and dose. Areas of high priority will include refining the biokinetic model for lead and developing similar biokinetic models for other heavy metals, developing predictive models for the bioavailibility of soil-borne contaminants, validating models for dermal exposure, refining estimate for soil ingestion rates, and developing stochastic tools, such as Monte Carlo techniques, to evaluate variability and uncertainty in exposure and risk estimates. Research evaluating the bioavailability of soil-borne contaminants

will include the use of toxicologic studies on animal subjects (e.g., swine) to measure contaminant uptake, absorption, and delivered dose to the target organ.

Anticipated Major Products

- Biokinetic uptake model for evaluating the toxicity of lead; By correlating levels of lead in soils to levels of lead in the bloodstream of human receptors, the biokinetic model makes much more certain predictions of risk than conventional risk models. Most of the effort will be on applying the model with field data from actual Superfund sites. (98)
- A national data base describing human activity patterns associated with human contact to soils and a report describing how various factors affect soil adherence. (98)
- Statistical distribution for exposure factors relating to exposure to soil-borne contaminants: soil intake rates, frequency of various human activities, bioavailibility of contaminants, inhalation rates, dermal contact rates, body weight, body surface area, and life expectancy. (98)
- Journal article describing a study measuring soil ingestion in children in the Richland, Washington area. (99)
- Journal article and report describing the results bioavailability studies of soil-borne contaminants using test animals. (00)

Estimating Soil Intake and Dose by Wildlife Species

Current Research Activities

Currently there is no activity underway is this research area funded by the Waste Research Program. However, later this year, work is expected to begin on a project (directly funded by the Superfund office) to develop ecotoxicity screening values for soil and sediments. Initially, screening values would be developed for 5-10 contaminants that are currently known to bioaccumulate in terrestrial food webs and have been observed to result in adverse impacts in higher trophic level species.

Future Research Activities

Eventually, ecotox screening values will be derived and validated for the 50 most common Superfund contaminants found in soil for terrestrial plants, invertebrates, microbes, birds, and mammals. Wildlife species are especially vulnerable to soil contamination since they have much direct contact with contaminated soils and feed on species that reside in soil. To properly evaluate risks to wildlife from soil-borne contaminants, it is necessary to develop exposure scenarios making critical assumptions about how contact could occurs. This would be facilitated with development of a multi-media wildlife exposure model.

Anticipated Major Products

- Ecotox screening values for 5-10 contaminants that are currently known to bioaccumulate in terrestrial food webs and have been observed to result in adverse impacts in higher trophic level species (PCBs, DDT/DDD/DDE, selenium, and methyl mercury). (98)
- Validated ecotox screening values for the 50 most common Superfund contaminants found in soil for terrestrial plants, invertebrates, microbes, birds, and mammals. (00)
- Develop a multi-media wildlife exposure model. (00)
- Develop a food web model that describes the feeding habits for organisms at various trophic levels. (00)

Remediation Research Activities

Biotreatment

This subsection describes soil/vadose zone bioremediation research activities in the following areas: 1) alternative endpoints/bioavailability, 2) natural attenuation, and 3) biotreatment. Natural attenuation research and biotreatment research for landfills is discussed under the last two areas, respectively.

One of the most important areas of remediation research for soils/vadose zone is on risk-based alternative cleanup endpoints. While innovative processes such as bioremediation are usually cheaper than conventional methods (e.g., incineration), they are sometimes not as effective in reducing contaminant concentrations to current cleanup goals, and require a longer period of time to achieve these goals. If treatment residuals do not actually pose the risks predicted by present methods of setting cleanup goals, then "alternative cleanup endpoints" could be set. The alternative endpoints would result in higher concentrations of residuals based on chemical analyses. However, with respect to toxicity to human or ecoreceptors, the relative toxicity using alternative endpoints would be equivalent to the projected risk based on chemical analysis, i.e., the level of protection to the receptors would the same. The focus of alternative endpoints research is currently on bioremediation, in order to investigate whether bioremediation residuals that are unavailable to degrading microorganisms are also unavailable (and therefore non-toxic) to humans and eco receptors. If this is true, then bioremediation (and other low energy *in situ* treatment techniques) may be much more widely applicable than at present, offering the potential for saving millions of dollars in remediation costs.

The objectives of the alternative endpoints part of the bioremediation research program are to determine the risk-reduction effectiveness of various remediation processes based on these assays. The assays would be selected (or developed) in a complementary research activity: "Development and Validation of Ecological Screening Tests for Treatment Residuals" discussed earlier in this section.

Given the proper conditions, naturally-occurring bioprocesses in the vadose zone can effectively degrade and/or stabilize hazardous substances. Therefore, in some cases, natural attenuation (NA) can be used as a follow-on to active treatment or by itself. The regulated community is actively pursuing the use of NA. However, particularly for the vadose zone, we have not yet fully developed the underlying science to support the decision-making on the use of NA. When we are more fully able to assess the capabilities and limits of NA, Regional and State personnel will be able to make more informed decisions on the use of NA. Therefore, a second objective of the soil/vadose zone bioremediation program is to more fully understand the natural capacity of these systems to assimilate these wastes and the conditions under which this occurs.

During the 1990's biotreatment has significantly reduced cleanup costs at sites with readily biodegradable contaminants. The application of bioventing and natural attenuation to petroleum hydrocarbon contaminated sites is estimated to have saved hundreds of millions of dollars compared to using more traditional dig and treat techniques. Biotreatment processes hold the potential for reducing costs of site contaminated with more complex contaminants, such as PAHs and chlorinated solvents. Therefore, one objective of the soil/vadose zone bioremediation program is to develop more-cost effective processes to enhance the biodegradation of contaminants found in soils and the vadose zone.

Current Research Activities

The two major efforts in bioremediation are focused on alternative endpoints and natural attenuation. Associated with alternative endpoints, are evaluating the effectiveness of natural attenuation and active bioprocesses to assess their effectiveness in toxicity reduction.

Alternative endpoints laboratory and field studies are being conducted in FY97 at PAH-contaminated sites. Available ecoassays will be utilized to screen residuals from natural attenuation, bioventing, phytoremediation and land treatment. Parallel studies are proposed for residuals from biotreatment of PAHs in other soil matrices.

Research activities are planned for FY97 on natural attenuation of contaminants in soils and the vadose zone and for landfills. Laboratory and field studies are being conducted to determine the conditions and contaminants for which NA is effective, with particular emphasis on PAHs in aerobic environments and on natural attenuation of vapors and contaminated leachates associated with the fill and contaminated ground water. The results of this work would be incorporated into protocols that will guide site managers on NA selection and implementation.

ORD's biotreatment research activities have been shifting focus to *in situ* processes (e.g., bioventing) for the past several years because *ex situ* processes (e.g., slurry

bioreactors) are more expensive. ORD is currently focusing on several enhanced-bioremediation research areas: 1) phytoremediation, 2) bioimmobilization of metals, 3) biodegradation of chlorinated organics utilizing mesophilic methanotrophs, and 4) bioventing. Studies area being conducted on the basic mechanisms which make phytoremediation effective, including rhizofiltration, phytoextraction, phytodegradation and enhance rhizosphere microbial degradation. Depending upon the mechanism, phytoremediation can be conducted to be either a method of enhanced biodegradation, or a natural attenuation process. Laboratory and field studies are also being conducted to determine the range of environmental and contaminant conditions under which the phytoremediation may be applicable. Specific contaminants being evaluated are PAHs, PCBs, TCE, petroleum hydrocarbons and metals.

Bioimmobilization research is investigating the basic processes which concentrate heavy metals and render them insoluble and thus immobile and/or nontoxic. Studies are being conducted on bacterial isolate that can be applied to lead to determine how to optimize the treatment process. Work is planned to determine if bioimmobilization can be applied to other heavy metals, specifically Hg and Cd. We are also conducting field studies of the bioventing of TCE. Laboratory and related field studies for the degradation of TCE through reductive dechlorination and biodegradation are also in progress, as is described in the abiotic research activity write-up of this section.

Anaerobic/aerobic bioventing is currently being evaluated in bench pilot systems for degradation of TCE and PCE in unsaturated soils. Field study assessments should be started in the near future.

Future Research Activities

Research will continue on the evaluation of the effectiveness of bioremediation to various contaminants and soil matrices utilizing screening assays to determine whether risk-based alternative endpoints are being met. Studies of bioremediation of pesticides, PCBs and metals will be conducted.

Research on natural attenuation in soils will focus on field validation and then to development of protocols for its application to: a) PAHs in aerobic and anaerobic conditions, and b) higher molecular weight hydrocarbons (e.g., pesticides, PCBs) under varying environmental conditions (e.g., soil porosity, and moisture and nutrient content).

A comprehensive evaluation of the potential for natural attenuation at landfills will be undertaken. Laboratory and field studies will be conducted to determine the biodegradative capacity within the fill and fate and transport of contaminants. Research will be carried out to assess the impact upon ground water as well as potential air emissions. This research on NA will also be complemented by evaluating

active control measures such as selective soil covers, evapotranspiration and leachate recycling.

Research will continue on phytoremediation as a component of natural attenuation and enhanced biodegradation until sufficient information is available on the major environmental processes and parameters that influence the selection and implementation of the technology that the process begins to be used in the private sector. This will involve completing laboratory research to identifying the major process(ES) that make phytoremediation effective and evaluating how to most cost-effectively apply it in the field to site conditions and contaminants for which it can make a significant improvement to existing cleanup options. Specific contaminants which will be evaluated are chlorinated solvents, metals, PAHs, PCBs, petroleum hydrocarbons, and potentially, radioactive wastes.

Research on enhanced-biodegradation basic processes applied in the soil/vadose zone will shift from studies of the application of electron acceptor/donor systems to include thermophilic systems because of their potential to perform in conjunction with electrokinetics. Processes such as Lasagna (TM) elevate soil temperatures through electrokinetic movement of contaminants, and thermophilic organisms will better survive in this regime (150°F). Further development of treatment schemes utilizing thermophilic organisms will have wide application to the treatment of process wastes and soils that have been subjected to processes such as thermal desorption. Studies of bioimmobilization of metals will also continue, with an expansion of the list of metals being investigated, potentially including not only mercury (Hg) and cadmium (Cd), but also selenium (Se), chrome (Cr) and arsenic (As). Research on enhanced-bioremediation for these processes will move from bench scale investigations to field optimization studies.

Anticipated Major Products

- Report comparing effectiveness of bioventing, phytoremediation, land treatment and natural attenuation on PAH contaminated soil (00).
- Technical resource documents on the evaluation of alternative treatment endpoints for PAHs (01).
- Report on natural attenuation of PAHs in soils (00).
- Technical resource document (TRD) on the implementation of phytoremediation (99).
- Draft protocol on NA of PAHs in aerobic environments (98).
- Report of decision support system for NA of contaminants in the vadose zone (98).
- Draft protocol on NA of metals (99).
- Draft protocol on NA of higher molecular weight organics (e.g., pesticides, PCBs) (00).

- TRD on the bioimmobilization for metals (99).
- Report on application of thermophilic organisms for biodegradation (99).
- Draft protocol for NA of petroleum hydrocarbons (98).
- Report Microbial Community Dynamics of PCB Dechlorination in Sediments (External Grant) (00).
- Report on Influence of Nonionic Surfactants on the Bioavailability of Chlorinated Benzenes for Microbial Reductive Dechlorination (External Grant) (00).

Abiotic Treatment

Abiotic treatment of the soil/vadose zone involves applying physical or chemical processes to contaminants to extract, degrade or immobilize them (sometimes in combination with containment or biological treatment.) ORD's abiotic research activities are currently focused in several areas. Delivery systems for *in situ* remediation are intrinsically important for all types of *in situ* remediation and containment systems, yet many obstacles are faced in application due to site heterogeneities and depth of contamination. Chemical treatment (degradation and immobilization) processes have selected areas of application where they hold the potential of improving *in situ* remediation effectiveness at a reduced cost. Immobilization technology also has a tremendous potential for cost-effectively solving the widespread metals contamination problems associated with mining and smelting operations, as well as providing potential solutions to the urban problems such as lead in soil. The associated research to define metals desorption phenomena will also impact cost-effective soil washing processes and *in situ* separation or leaching techniques. In addition, ORD's SITE program (described elsewhere in this section) evaluates abiotic remediation processes and the results are integrated with ORD research results to guide the abiotic research program and to develop comprehensive remediation technology transfer instruments.

Treatment of non-aqueous phase liquids (NAPLs) is discussed under abiotic research activities in the section on contaminated ground water.

Current Research Activities
ORD extraction research is focusing on extracting (and containing) NAPLs. Since NAPLs exist in both the saturated and unsaturated zone with the most complex problems in the former, this research is described in the aquifer research activity section, above.

A second thrust of abiotic treatment research is to develop reactant delivery systems and associated *in situ* techniques for soil treatment. Hydraulic fracturing has been developed as a means of reactant delivery in low-porosity subsurface matrices (e.g., clay). The Lasagna (TM) process utilizes a combination of hydrofracturing, electrokinetics and contaminant treatment processes such as reductive dechlorination or biodegradation to move contaminants through low-porosity matrices and treat them in the fracture. Current ORD research is focusing on the treatment of contaminants using microorganisms (both methanotropes and thermophilic organisms) or using zero-valent metals to dechlorinate compounds such as trichloroethene (TCE). Laboratory studies continue to investigate the geochemistry of TCE degradation in aqueous and soil slurry systems.

Research is also underway to understand the solubility/adsorptive behavior of chemicals in the environment, as those properties affect their bioavailability, and to attempt to apply that understanding to remediation of environmental contamination. To date, comprehensive experiments have been performed on the behavior of lead and lead species, concentrating on the formation of highly insoluble and bio-unavailable compounds. Related laboratory work is also pursuing the study of lead-concentrating organisms as a venue for rendering lead insoluble. Potential exists for combination chemical/biological treatment of lead-contaminated soils and sediments. Simple mathematical models have also been developed for the adsorption kinetics of organic compounds on soil particles, and preliminary experimental work has been performed with metals.

Future Research Activities
Future work on contaminant extraction will continue to focus on NAPL extraction in the saturated and unsaturated zones, as described in the aquifer research activity section above.

In situ treatment work for dechlorination of TCE will continue through FY98. Both lab and field studies will continue to refine results and investigate new techniques. Lasagna field work will drop off by FY99 if results do not lead to continued research needs. Hydraulic fracturing as a delivery tool will continue as a modest research effort associated with delivery of containment systems.

In the area of soil-contaminant interaction, a number of activities will continue through FY00. Immobilization studies will end in FY98 for lead, and begin to focus on other metals such as Hg, As, Cd, and Cr. Future work is planned in using nontraditional approaches to immobilization such as the *in situ* formation of metal phosphates or sulfides rather than forming soil concrete units or grouted soil columns. In the area of adsorption/desorption, FY98-00 research will refine the results of laboratory and field work on organics and will expand into phenomena that affect metals/inorganics. This research on sorption kinetics is the laboratory continuation of the former soil washing program, and will provide the data necessary to design remediation schemes involving soil washing, *in situ* flushing and electrokinetics. The focus of these efforts will be either on anionic aspects (arsenic, chromium) or cationic species of better-known adsorptive properties (e.g., mercury), depending on the results of a more-complete literature review.

Anticipated Major Products

- Results of electrokinetic reductive dechlorination experiments on TCE, Journal Article (98)
- Field Manual for Lasagna - EPA Report (99)
- Manual for Application of Thermophilic Organisms Used in Lasagna Process, Journal Article - (00)
- Technical Resource Document on Bacterial Concentration of Heavy Metals. (99)
- Manual on Cost Engineering for Hydraulic Fracturing (99)

Containment

Cleanup of contaminated soils or abandoned waste facilities and general site restoration (ecological restoration) often involve containment systems (particularly caps) as temporary or permanent remediation remedies. Containment technology is a universal tool and when considered on the component level can be applied at a wide variety of sites. Containment may include solidification/stabilization of soil and waste material; isolation of wastes through construction of impermeable side walls (slurry walls, geotextiles, cryogenic barriers, etc.); construction of caps and covers for control of infiltration; placement of remedial bottom layers under existing or leaking facilities (hydraulic fracturing for installation of low permeability materials); innovative techniques for installation of geotextiles; and remedial treatment of clays and existing containment barriers. However, the short- and long-term effectiveness of the systems are often not well understood. EPA needs to conduct research to enhance the development of effective containment options, understand how long they will last and what their lifetime operation and maintenance (O&M) costs will be.

Current Research Activities

NRMRL's current research effort is measuring the performance and identifying any problems with landfill containment technologies, and cover and capping techniques for steep slopes. Primarily, the research focuses on newly developed geosynthetics. EPA's existing guidance on construction quality assurance and quality control will also be assessed. Interim results show that containment options are generally effective, but some design and performance assumptions need to be corrected or updated to take new products and developments into account for future facilities.

Future Research Activities

Future work will revise and strengthen EPA's final cover guidance, which is now out of date. The existing guidance is fundamentally sound, but makes no mention of new material (like geosynthetic clay liners [GCLs]) and techniques. Emphasis on seismic stability issues make cover guidance revision important, as much of the nation finds itself grappling with seismic design requirements. EPA has design guidance for seismic analysis, but cover guidance on this issue is incomplete.

NRMRL plans to conduct research in FY98 and FY99 in the area of long-term stability of clay barrier materials, often thought to change hydraulic properties over time, rendering them ineffective. Effects of chemical leachates and pH changes on clay materials will be studied. Additives may be developed to stabilize these layers, guaranteeing their performance over longer periods of time. Additionally, work would begin a comprehensive examination of the degradation properties of geomembranes used in waste containment, in order to learn the changing properties of the use of polymeric liners in environmental applications. This area would require additional resources in FY98 and FY99 to complete. Application of these research results will improve containment options for hazardous waste sites, as well as upgrade designs for handling material from removal operations or hazardous waste landfills.

The potential to work with other agencies remains high. Military bases are undergoing realignment and closure, and often require the correction of environmental problems at the site. US DOE continues to remediate contaminated sites, and for many mixed waste sites, containment may be the only cost-effective alternative. Sandia National Laboratory has ongoing research in alternative cover designs as they attempt to evaluate covers for use in arid climates. Cold climates also require special consideration in containment.

Anticipated Major Products

- Final cover guidance revision - (99)
- Comprehensive report on GCL use in the design containment systems for steep slopes (98)

Demonstration and Verification of Innovative Remediation Technologies
Technology buyers and users need high quality data and engineering information on the performance of innovative remediation technologies in order to make cleanup decisions at Superfund and RCRA Corrective Action (CA) sites. Credible cost and performance data will also become increasingly important in the larger scheme of restoring contaminated ecosystems. In addition, the environmental community is continually searching for new cost-effective technologies that prevent, control, and destroy pollution. The need for the demonstration and verification of innovative technologies for hazardous waste remediation, monitoring and ecosystem restoration is expected to continue into the year 2000 and beyond.

The Superfund Innovative Technology Evaluation (SITE) Program was developed in response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), to encourage the development and implementation of innovative treatment technologies for hazardous waste site remediation. The objective of the program is to produce credible performance data on full-scale technologies applied to real world situations. A second objective is to encourage the development and implementation of innovative technologies.

The SITE Program is an integral part of ORD's Superfund research program, giving ORD the capability to integrate its own research and development expertise with the evaluation of vendor's processes and to treat priority EPA remediation problems such as *in situ* bioremediation techniques, engineered reactive systems for ground water treatment and advanced containment systems. The SITE Program also works cooperatively with DOE and DOD, to bring the benefits of an established, objective evaluation program to the assessment of technologies for rapid, cost-effective federal facility cleanup.

Current Research Activities
The remediation technology component of the ORD SITE Program consists of two parts: a demonstration program and technology transfer activities. The Demonstration Program enters into cooperative arrangements with private developers of technologies to evaluate innovative remediation technologies that are at or near commercialization. In FY97, the SITE program is developing stronger relationships with waste site owners and SITE in selecting remedial technology options so the property owners and SITE program can match innovative technologies to high priority contamination-problems. Site owners will be responsible financially for site preparation and waste disposal, technology developers are responsible for development and operation of their units at contaminated sites, while the SITE Program is responsible for test plan development, collecting technology performance and cost data, assuring data quality and objectivity, and publishing the test results. The program is publishing a bulletin describing its new

operational approach ("SITE: Innovation on the Move") and will also publish a marketing report in late FY97 or early FY98.

Technology areas of primary interest are treatment technologies for both metals and organics in ground water; treatment technologies for metals in soils and combinations; combined methods for improved delivery and/or recovery along with *in situ* remediation operations and chemical conversion methodologies; and *in situ* and onsite bioremediation processes for contaminated soil containing compounds that are resistant to biodegradation. Cutting across all of these technology areas is the emphasis on identifying low cost technologies.

Besides technology demonstration reports, SITE publishes an annual summary report on the status of its demonstrations and makes demonstration results available electronically on the Alternative Treatment Technology Information Center (ATTIC) and through the Internet. In FY97, SITE will initiate comparative analyses of specific types of remediation technologies (e.g., thermal desorption) or technologies application to specific types of sites or contaminants.

Future Research Activities

The SITE remediation program will continue to conduct demonstrations on innovative technologies that meet the highest priority environmental problems, as defined by market and regulatory needs. Also, the program will expand its activities to develop technical resource documents (TRD) which evaluate innovative remediation options for various types of contaminated sites or remediation options. From FY98 through FY00, SITE will emphasize remediation options in the following additional areas:

- PAH and PCB contaminated soils
- Contaminated sediments
- High-priority Brownfields problems
- Explosives residuals in soils
- Unexploded ordinances

Anticipated Major Products

- Fungal Treatment Technology Capsule Summary and Innovative Technology Evaluation Report (ITER) (97).
- X-TRAX Thermal Desorption System Capsule Summary and ITER(97).
- Sonotech, Inc. Combustion System ITER (97).
- Grace Dearbon Biotreatment System ITER (97).
- Technical resource document on application and design of permeable reactive barriers (99).
- TRD on technologies applicable to remediation of metals in soils (99).
- TRDs on other technology or contamination types (TBD)

Oil Spills

ORD's Oil Spills Research Program focuses on remediation options for petroleum products that have spilled into navigable surface waters (i.e, spills covered by the Oil Pollution Act [OPA] of 1990). As described earlier in this research plan, the economic and ecological impact of such spills can be substantial (as may be the health effects impacts for freshwater spills, although health effects are less well documented). Much of ORD's activities on oil spills is focused on bioremediation, as EPA is the lead Federal agency for this research. The objectives of the Oil Spills Research Program are to develop and evaluate improved means for remediating spills and to determine the risks associated with remediation options.

Current Research Activities

ORD is completing several activities associated with remediation options for marine environments and is shifting its research focus to spills in freshwater. Development of chemical countermeasures protocols for dispersents and surface washing agents is expected to be completed by the end of FY98. Evaluations of the ecological impacts of chemical countermeasures are being initiated. Research is ongoing on the optimum means of applying washing agents to enhance marine shoreline bioremediation, including evaluations of how environmental factors and oil characteristics influence the effectiveness of biodegradation. Evaluations of techniques for predicting the fate of biodegradation residuals in the marine environment are also being conducted.

Evaluations of the effectiveness of bioremediation for cleaning up and restoring wetlands are being conducted. Also, a protocol for determining the effectiveness of bioremediation in marine environments is being adapted for freshwater environments.

Future Research Activities

Studies of the ecological impacts of chemical countermeasures in marine and freshwater environments will continue. Evaluations of the applicability of bioremediation in marine shorelines will be completed by FY99(?) and bioremediation research will continue to shift to problems from oil spills in freshwater environments. Research will be conducted on the effects of inland spills on freshwater environments with an increased emphasis on health effects due to the potential of spills affecting drinking water supplies, as well as the freshwater food chain.

In addition, ORD is evaluating the importance of conducting research on the ecological impacts and remediation options for edible-oils spills.

Anticipated Major Products

- Production of revised swirling flask test protocol (98).
- Draft guidance document for application of bioremediation for marine shorelines (98).
- Production of a protocol for testing bioremediation agents effectiveness in freshwater environments (98).
- Draft guidance document for application of bioremediation of freshwater environments (00).

Monitoring Research Activities

Field and Screening Analytical Methods

Current Research Activities

Analytical methods developed under this research activity include methods for soils, soil gas, and the air around hazardous waste sites. Most of the research described under the previous section (Contaminated Sites - Ground Waste) is also applicable to soils and the vadose zone and, therefore, will not be repeated here.

Research in the application of advanced instrumentation to air and soil characterization focuses on methods that will provide high-quality data rapidly with simple and rugged protocols. Emphasis is on technologies that can eventually be used to perform analysis in the field, those that can determine pollutants that are intractable by conventional EPA methods, as well as those that improve risk assessments by providing specific information on the most hazardous forms of pollutants. Specific areas of investigation in FY 97 include gas chromatography/atomic emission detection (AED) as a simple, reliable and potentially field portable technique for measuring organic pollutants containing heteroatoms (e.g., pesticides); capillary electrophoresis (CE) for very rapid analysis; the combination of CE with laser-induced fluorescence (LIF) detection for potentially field-portable analysis; and elemental speciation methods for measuring concentrations of the most hazardous forms of inorganic pollutants.

Innovative methods that are currently evolving through the state-of-the-art phase to a more mature phase of development include: (1) open path methods for the analysis of air samples above and along the perimeter of waste storage sites and (2) field portable and field transportable instrumentation the can be used at waste storage sites for real time or near real time characterization of sampled air. More fundamental research on the use of solid sample extraction by both super critical fluids and the so-called enhanced-fluidity liquids have opened up new possibilities for sample analysis. The examination a new generation of open path systems based on differential absorption spectroscopy (DOAS) is beginning in FY97.

The recent advances in instrumentation for fast gas chromatography and for rapid scan rate time-of-flight mass spectrometers (TOF/MS) have been combined in an EPA in-house project to produce definitive mass spectra in one tenth the time typically taken with routine monitoring instrumentation. Measurements at waste storage sites that are time-sensitive will obviously benefit from this development if reliable operation can be demonstrated. Reduction in size of components and enhancements in instrument portability are appearing in commercial instrumentation and will be examined in field studies during simulated release of trace gas species.

Future Directions

The teaming of immunochemical methods with instrumental analysis will continue to be developed. Super critical fluid extraction (SFE) coupled with immunoassays can provide methods that are highly quantitative. Immunoaffinity chromatography sample preparations can streamline sample preparations for mass spectrometry. These multiple technology approaches exploit the advantages of two different technologies and provide powerful analytical capabilities. Multi-analyte immunoassay formats will be investigated for field applications. The development of methods to support toxicological and pharmacological studies will also continue.

Research in waste monitoring technologies based on advanced instrumentation will be influenced by several developments in site characterization.

- The trend toward field methods will continue. Once laboratory CE methods are developed and demonstrated, the technology should be well suited for field use. Very rapid, field-portable sample preparation technologies will also be developed.
- Natural attenuation as a remedial option is becoming accepted. Monitoring methods for initial site characterization and for assessing the efficacy / performance of this approach must be made available.
- More sophisticated estimates of risk based on element speciation information are allowing the increased use of alternative remedial goals. The speciation methods for a number of pollutants in multiple media must be developed and evaluated.

Anticipated Major Products

- Biosensors for Environmental Monitoring (97/98)
  - KinExA Method for Screening 2,4-D
  - Phosphotriesterase-based Biosensor for Detection of Organophosphates
  - Biosensor Technology for Environmental Monitoring
- Immunochemical Methods for Environmental Monitoring (97/98)
- Enzyme-electrode Biosensor for Screening of Phenolic Compounds at Superfund Sites (97/98)

- Tyrosinase-based Biosensor for Measurement of Phenolics- contaminated Soils and Sludges
- Immunochemical Techniques For Co-Planar Polychlorinated Biphenyls (97/98)
- Open-Path FT-IR Monitoring (97/98)
- Time-Of-Flight Mass Spectrometer(TOFMS)/Fast GC Combination for Rapid Analysis (97/98)
- Methods for the Speciation of Inorganics in Environmental Samples (97)
- Multi-laboratory Evaluation of Pesticide Screening by Gas Chromatography / Atomic Emission Detection (97)

Field Sampling Methods

Current Research Activities

Nearly all research programs require the collection of samples in the field. However, the overwhelming majority of efforts (in terms of time and cost) to control and quantify error components in the resultant data are concentrated on the laboratory analysis of the samples. It has been repeatedly shown that 80 percent of the total measurement error occurs in the field for the more stable contaminants (e.g., metals, PCBs, and pesticides) and up to 99.99 percent of the total error occurs in the field for non-stable contaminants (e.g., volatile organic compounds). Research is being conducted to develop scientifically sound approaches to assessing and characterizing risks to human health and the environment associated with improper sample collection and handling techniques and to provide credible state-of-the-science methods and guidance on how to properly collect samples in the field such that sample integrity is maintained. Matrices under investigation include soils, sediments, and other solid matrices (e.g., solid wastes). Currently, research is being conducted in three major areas: (a) on improving the sampling of volatile organic compounds in soils, (b) to examine the leading particulate sampling theories as they relate to reducing errors associated with soil sampling for both inorganic and organic contaminants, and the development of enhanced performance methods analysis applying robust statistical techniques to generated data. By investigating these areas of concern, new and markedly improved sampling techniques will be developed to reduce the error associated with the field component of any program and thus provide more accurate site characterizations. Further, through the incorporation of results from this research program, improved sampling techniques and statistical data interpretation methods will be developed which will result in better data being used in exposure and risk assessments and in characterizing sites that require remediation.

Future Research Activities

Research will continue on the development of a new sampling device, to reduce the atmospheric losses of VOCs associated with soil sampling, with Phases II (testing on VOC-contaminated soils) and III (modification and reporting) of the project with an

estimated completion in late FY99. Continued efforts examining soil factors that influence the sorption and subsequent release of VOCs will be made with research topics expected to include: the effect of the degree of organic matter decomposition on VOC sorption, the effect of wetting fronts on VOC movement and release, improvement of sample preservation techniques, and conducting a methods comparison study providing a comprehensive examination of the most commonly used analytical techniques for VOC quantification on a common set of VOC-contaminated soils.

Examination of additional methods and techniques to improve sampling of soils, sediments, and other solid matrices will be performed through the initial testing of the leading particulate sampling theory on different distributions of metal contaminants in soils. Samples will be collected using different sampling tools and techniques ranging from "correct" sampling to commonly used field techniques. Ultimately, testing will be expanded to organic contaminants and "real world" settings as well as other matrices including sediments and other solid wastes. Continued research on robust statistical techniques to improve data quality and subsequent data interpretation will be performed to expand the number of techniques available to more accurately assess the true data moments (e.g., mean, standard deviation, variance, etc.).

Anticipated Major Products

- Soil Sampling for Characterizing Hazardous Waste Sites (97)
- Robust Statistical Methods for Environmental Application (98)

Sampling Design

Current Research Activities

This area of research will develop, test, and validate various strategies and computer algorithms for improving the cost-effectiveness of the sampling/estimation/decision process in characterizing and remediating contaminated soils and other solid wastes. The project will also provide computer tools and technical assistance in the area of sampling design and geostatistics.

The EPA's Data Quality Objectives (DQO) process provides a basic framework for environmental sampling, quality assurance, and data analysis. The DQO guidance stresses that the objective of sampling should be to make critical environmental decisions with an adequate degree of confidence at minimum cost. Little or no guidance exists on how to combine all of the elements involved in characterization and assessment to provide cost-effective decision-making. Nor are tools available for evaluating the cost-effectiveness of alternative design approaches such as field screening, indicator sampling, composite sampling, adaptive sampling, or combinations of these. The most recent statistical guidance from EPA provides an excellent cookbook of statistical tests, but none deal with multivariate data, combining data of different qualities, or data that are auto correlated in space or time.

EPA is attempting to develop a hazardous waste identification rule (HWIR) to de-list wastes that have been classified as hazardous, but may not be sufficiently so as to warrant EPA control. Many of the same sampling, estimation, and decision-making problems appear in this effort.

Statistical and geostatistical tools have been developed previously to improve the cost-effectiveness of the sampling/estimation/decision process in characterizing and remediating contaminated sites, and for reducing the uncertainty associated with such measurements. Three EPA-developed statistical programs, Scout, Censor, and Regress, will be merged into a Windows package. A robust kriging algorithm will be developed and added to Scout. Kriging is a minimum variance weighted average interpolation method used to estimate and map local contaminant concentrations based on relatively sparse and irregularly spaced sample data. Environmental applications are often multivariate, and currently there are no guidelines for multivariate kriging. Multivariate kriging methods will be evaluated and new robust multivariate kriging methods will be developed; both will be compared to more traditional geostatistical methods.

Future Research Activities

In-house research and development in sampling design optimization will be initiated as resources become available. This work will be directly oriented toward answering questions and providing tools related to cost-effective site characterization and decision-making. A large variety of sampling, measurement, and estimation methods is currently available. The site investigator has many choices to make: a single sampling event versus two or more phases; laboratory analysis versus field immunoassays; composite versus point samples; grid versus random sampling; ordinary kriging versus robust kriging. Research will focus on investigating the integrated effect of all of these choices on the quality of decision-making, and development will focus on computer tools to help the site investigator make appropriate choices given site-specific decision performance requirements. This research is also related to the research described under the Waste Characterization and Sampling activity in the Active Waste Management Facilities section.

Anticipated Major Products

- Windows Version of Scout Software (Statistical Analysis Software) (97).
- Expedited Site Characterization Guidance and Software on CDROM (97).
- Guidance Document for Cost-effective Site Characterization Through Geostatistical Sampling Design and Estimation (98).

Demonstration and Verification of Field Monitoring Technologies

Current Research Activities

Rapid, reliable and cost effective field screening technologies are needed to assist in the complex task of characterizing and monitoring of hazardous and chemical waste

sites. However, some environmental regulators and remediation site managers may be reluctant to use new site characterization technologies that have not been validated in an EPA-sanctioned testing program, since data from them may not be admissible in potential legal proceedings associated with a site or its cleanup. Until characterization technology claims can be verified through a scientifically sound, unbiased evaluation, the user community will remain skeptical of innovative technologies, despite their promise of better, less expensive and faster environmental analyses.

A program of monitoring technology verification has been implemented through the Consortium for Site Characterization Technology (CSCT) which is funded by the Superfund Innovative Technology Evaluation (SITE) program, the Environmental Technology Verification ETV program (part of the President's Environmental Technology Initiative (ETI), and the Department of Defense's Strategic Environmental Research and Development Program (SERDP). In addition, it is partnered with a number of other Federal, State, and private organizations, including the Department of Energy's technology demonstration programs.

The goal of the verification program is to identify, demonstrate, assess, and disseminate information about innovative and alternative environmental monitoring, measurement, and characterization technologies to developers, remediation site managers, and regulators. This is intended to be a principal source of information and support with respect to the availability, maturity, and performance of these technologies. The technology demonstration process clearly defines the performance assessment, evaluation, and verification pathway and includes the following components: technology selection, technology performance assessment, evaluation, and verification, and information distribution/dissemination via innovative technology verification reports.

Future Research Activities

The characterization and monitoring technology verification program will find many ready candidates for demonstration over the next few years. Researchers within and outside the government are developing new techniques and optimizing and miniaturizing existing technologies. The technology pipeline includes technologies ranging in maturity from first generation prototypes to commercially available. Some of the technologies on the demonstration horizon include a vast array of remote sensing techniques, miniaturized laboratory instrumentation, and geophysical methods. Some of the less mature technologies include surface acoustic wave devices for monitoring contaminants in water, air and soil gas; innovative geophysical techniques; new sensors for deployment by cone penetrometers; and ultrasonic sensors for *in situ* monitoring of physical properties.

Anticipated Major Products

The Innovative Technology Verification Reports (ITVR) are produced from each technology demonstration and document the performance of technologies that have participated in the verification program.

- Reports on six different technologies are anticipated from the field portable x-ray fluorescence demonstration.
- Reports on two technologies are anticipated from the portable GC/MS demonstration.
- Reports anticipated from the field portable analysis of mercury demonstration are:
  - Mercury Analysis in Soil using Immunoassay
  - Mercury Analysis in Soil using Electrochemical Techniques
- Reports from planned demonstrations, which are:
  - Demonstration of *In situ* Analyzers
  - Demonstration of PCB Analysis Methods for Water, Soils and Sediments
  - Demonstration of Soil Gas and Soil Sampling Devices

Summary Tables

The soils/vadose zone research plan summary sheet (Table E-1) lists the major product that ORD anticipates iw will generate as a result of each soils/vadose zone research activity. The table shows the fiscal year (FY) in which the product is projected to be generated, and indicates whether the work is currently funded or unfunded. A plus mark ("+") means that the product would be funded under the current allocation of ORD research funds. A minus mark ("-") indicates that funding is not currently allocated to this product. A product is considered "currently funded" if there would be adequate funds to develop and complete it under the proposed FY98 President's Budget and FY99 and FY00 budgets that are the same as the proposed FY98 President's Budget.

References

USEPA. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures.* Federal Register, vol. 51, no. 185, September 24, 1986.

USEPA. 1989. *Risk Assessment Guidance for Superfund* (Vol. 1. Human Health Evaluation Manual, and Vol. 2. Environmental Evaluation Manual). US Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. 1989.

Table E-1. Waste Research Plan Summary Sheet - Contaminated Soils/Vadose Zone
("+" = planned, funded product; "-" = anticipated, unfunded product)

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Hazard Assessment	Ecological Screening Tests to Measure the Effectiveness of Treatment	.....			
	- Technical Resource Document on Assays Applicable to PAHs in Soils			+	
	- Preliminary Report on the Correlation of FRAME Tests with Soil Toxicity		+		
	-Technical Resource Document on the Applicability of FAME Tests for Screening Soil Toxicity				+
	- Prototype Reactor, Simulating Complete Gastrointestinal System				+
	Mixtures Toxicology	.....			
	-Document evaluating constraints upon the additivity assumption				-
Exposure Assessment	None				
Risk Characterization	Estimating Human Exposure and Internal Dose	.....			
	- Biokinetic Uptake Model for Evaluating the Toxicity of Lead		+		
	- National Database Describing Human Activity Patterns Associated Contact to Soil		+		
	- Statistical Distributions for Exposure Factors Related to Soils		+		
	- Results of a Study Measuring Soil Ingestion in Children			+	
	- Report Describing the Results of Bioavailability Studies of Soilborne Contaminants Using Test Animals				+

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Estimating Soil Intake and Dose by Wildlife Species	.....			
	- Ecotox Screening Values for 5-10 Contaminants Known to Bioaccumulate		+		
	- Validate Ecotox Screening Values for the 50 Most Common Superfund Contaminants		+		
	- Develop a Multimedia Wildlife Exposure Model				+
	- Develop Food Wed Model that Describes the Feeding Habitats of Organisms at Various Trophic Levels				+

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Remediation	Biotreatment	.....			
	- Report Comparing Effectiveness of Bioventing, Phytoremediation, Land Treatment, and NA on PAH Contaminated Soil				+
	- Technical Resource Documents on the Evaluation of Alternative Endpoints for PAHs				+
	- Report on Natural Attenuation of PAHs in Soil				+
	- Technical Resource Document on the Implementation of Phytoremediation			+	
	- Draft Protocol on NA of PAHs in Aerobic Environments		+		
	- Report on Decision Support System for NA in the Vadose Zone		+		
	- Draft Protocol on NA of Metals			+	
	- Draft Protocol on NA of Higher Molecular Weight Organics				+
	- Technical Resource Document on Bioimmobilization for Metals				+
	- Report on Application of Thermophilic Organisms for Biodegradation				+
	- Draft Protocol for NA of Petroleum Hydrocarbons			+	
	- Report on Microbial Community Dynamics of PCB Dechlorination in Sediments (External Grant)				+
	- Report on Influence of Nonionic Surfactants on the Bioavailability of Chlorinated Benzenes for Microbial Reductive Dechlorination (External Grant)				+
	Containment	.....			
	- Final Cover Guidance Revision			+	
	- Comprehensive Report on GCL Use in the Design of Containment Systems for Steep Slopes		+		

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Abiotic Treatment	.....			
	- Results of Electrokinetic Reductive Dechlorination Experiments on TCE		+		
	- Field Manual for Lasagna Process			+	
	- Manual for Application of Thermophilic Organisms Used in Lasagna Process				+
	- Technical Resource Document on Bacterial Concentration of Heavy Metals			+	
	- Manual on Cost Engineering for Hydraulic Fracturing			+	
	Oil Spills	.....			
	- Production of Revised Swirling Flask Test Protocol		+		
	- Draft Guidance Document for Application of Bioremediation for Marine Shorelines		+		
	- Production of Protocol for Testing Bioremediation Agents Effectiveness in Freshwater Environments		+		
	- Draft Guidance Document for Application of Bioremediation to Freshwater Environments				+
	Demonstration / Verification of Innovative Remediation Technologies	.....		+	
	- Fungal Treatment Technology Capsule Summary and Innovative Technology Evaluation Report (ITER) (97)	+			
	- X-TRAX Thermal Desportion System Capsule Summary and ITER (97)	+			
	- Sonsotech, Inc. Combustion System ITER (97)	+			
	- Grace Dearbon Biotreatment System ITER (97)	+			
	- Technical Resource Document on Application and Design of Permeable Reactive Barriers			+	
	- Technical Resource Document on Remediation of Metals in Soil			+	

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Monitoring	Sampling Methods	.....			
	- Soil Sampling for Characterizing Hazardous Waste Sites	+			
	- Robust Statistical Methods for Environmental Applications		+		
	Field and Screening Analytical Methods - Soils	.....			
	- Biosensor for Environmental Monitoring		+		
	- Immunochemical Methods for Environmental Monitoring		+		
	- Enzyme-electrode Biosensor for Screening Phenolic Compounds at Superfund Sites		+		
	-Immunochemical Techniques for Co-Planar Polychlorinated Biphenyls		+		
	- Open-Path FT-IR Monitoring		+		
	- Time-of-Flight Mass Spectrometer/Fast GC Combination for Rapid Analysis		+		
	- Methods for the Speciation of Inorganics in Environmental Samples	+			
	- Multi-laboratory Evaluation of Pesticides Screening by GC/Atomic Emission Detection	+			
	Sampling Design	.....			
	- Windows Version of Scout Software	+			
	- Expedited Site Characterization Guidance and Software of CDROM	+			
	- Guidance Document for Cost-effective Site Characterization through Geostatistical Sampling Design and Estimation		+		

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Monitoring Technology Demonstration (SITE)	.....			
	- Reports of Six Different Technologies from the Field XRF Demonstration	+			
	- Reports on Two Technologies from the Portable GC/MS Demonstration	+			
	- Reports on Two Technologies for the Field Portable Analysis of Mercury Demonstration		+		
	- Reports of Planned Demonstrations: In situ Analyzers; PCB Methods; and Soil Gas and Soil Sampling Devices			+	+

Appendix F
Preliminary Research Plan
Active Waste Management Facilities

Contents

Preliminary Research Plan
Active Waste Management Facilities

Introduction

The current regulatory approach to the management of hazardous wastes is considered extremely burdensome and costly to the US economy. In addition, the regulations are considered overly conservative and not well-founded on risk. As a result, the Administration is proposing regulatory reforms to provide administrative and economic relief by developing a multimedia, multipathway risk-based approach that is expected to exclude many wastes and waste streams from regulatory control under Subtitle C of RCRA (Hazardous Waste Identification Rule [HWIR]). For this new regulatory approach to be successful, significant new research is needed to provide the science underpinnings.

In addition, acceptable disposal of hazardous wastes is specified by Land Disposal Restriction (LDR) rules. As part of these rules, Best Demonstrated Available Treatment (BDAT) technologies are specified that must be used to treat the waste prior to disposal. BDAT technologies were identified for each hazardous waste stream in the late 1980s and early 1990s and were based on the most effective treatment technologies that were commercially available at the time. It was recognized that there were some hard-to-treat wastes for which available technologies were either not sufficiently effective, or were very expensive, and that ongoing efforts would be needed to upgrade the BDAT technologies for a limited number of hazardous waste streams.

OSWER and others have identified a set of research needs (see Table 2-2 and Appendix B) related to the above issues. In response, ORD has developed the following set of proposed research activities. The funding status and schedule of products from these activities are summarized in a table at the end of the appendix.

Proposed Research Activities

Hazard Assessment Research Activities

As was described under the Contaminated Ground Water Topic Area, hazard assessment is comprised of two major activities-- hazard identification and dose-response assessment. The only hazard assessment research activity that is proposed under this research topic would be to develop toxicity values (reference doses, reference concentrations, and cancer slope factors) where none are presently available. Without toxicity values, risks from those contaminants can not be quantified.

Developing Provisional Toxicity Values for Contaminants

Current Research Activities

Currently there is no work funded in the Waste Research Program to derive toxicity values for contaminants. ORD's Integrated Risk Information System (IRIS), which is funded under ORD's Multimedia Research Program, does develop consensus toxicity values for the Agency, but only for a very limited number of chemicals.

Future Research Activities

If funding were to become available, research would be undertaken to develop *consensus* toxicity values through the IRIS project for chemicals of concern to the office of Solid Waste or develop *provisional* toxicity values using limited toxicity data (structure activity relationships, animal data, or epidemiological studies).

Anticipated Major Products

None are currently planned due to a lack of funding. However, if funds were to become available, the following products could be produced:

- 25 IRIS endorsed consensus toxicity values (99)
- 50 provisional toxicity values (98)

Exposure Assessment Research Activities

Multimedia, Multipathway Exposure Modeling

Current Research Activities

This research is intended to develop a Framework for Regulatory Analysis and Management of Environmental Systems (FRAMES) for the purpose of facilitating the consistent and scientifically credible assessment of multimedia-based human and ecological exposure to chemical stressors at geographic scales ranging from waste sites to watershed. FRAMES will establish a conceptual linkage among the following components of EPA's multimedia-based regulatory development process: regulatory decisions, risk-based assessment methods, model/database development, field studies, and bench science. FRAMES will be a computer-based environmental information processing system that will contain databases, problem conceptualization guidance, simulation models and application strategies, uncertainty assessment processors, and extensive data processing software. FRAMES will not be "a" model or "a" database, instead, FRAMES will be a state-of-the-art computer software system that 1) houses a set of core exposure assessment tools (i.e., databases, models, assessment protocols, etc.), 2) communicates with external software systems, models, and databases for the purpose of exchanging and processing exposure assessment information and data, and 3) provides a computer environment for the efficient assimilation of new science in the fate, transport, and transformation of contaminants.

Future Directions

A number of research needs have surfaced as a result of ongoing critical review of EPA exposure and risk assessment methods by the Science Advisory Board. Among the top priorities for focused science and engineering research are the following:

- Quantification of Uncertainty
- Performance of National Scale Exposure Assessments
- Environmental Chemistry of Mixtures
- Chemical Fate Processes per Environmental Medium per Phase
- Determination and Parameterization of Critical Exposure Pathways
- Evaluation of Compartmental Models
- Assimilation of Science Outputs from the Scientific Community

Anticipated Major Products

- User's Manual for Windows-based SPARC Properties Calculator (97)
- Incorporation of SPARC-based, Automated Fate Parameterization Techniques into the Ground Water Modeling System (97)
- Rewrite of the Multipathway Exposure and Risk Analysis Science Plan (97/98)
- Beta Test Version of Multimedia Framework Linking the Screening Models MEPAS, MMSOILS, and RESRAD Together (97/98)
- Experimental Validation and Reliability Evaluation of Multimedia Risk Assessment Models (External Grant) (99)

Environmental Fate and Transport, Physical Estimation

Current Research Activities

Present exposure assessment modeling techniques do not adequately account for many important contaminant speciation processes that impact the transport and fate of contaminants in natural environments. This research focuses on reducing the uncertainty associated with exposure assessment modeling predictions by providing improved, process level models for quantifying pollutant interactions (sorption and speciation mechanisms) in a variety of natural systems. The focus will be on metals speciation, sorption, and complexation processes, partitioning behaviors of endocrine disruptors, characterization of redox environments associated with natural systems, and the development of improved thermodynamic databases for geochemical speciation modeling systems.

This research also focuses on the development of improved, process level models and databases for quantifying pollutant degradation rates and mechanisms in soil, sediment, and water systems. The goal is to augment present predictive modeling capabilities through the development of integrated pollutant transformation algorithms that address biological, chemical, redox, and enzyme mediated transformation mechanisms under a single, integrated modeling formalism that can be driven by predicted or available input parameters.

Future Research Activities
This work is closely related to the Office of Solid Waste's (OSW) regulatory decision strategy for land disposal of hazardous wastes. Future efforts will necessarily have to mesh with developing regulatory strategies and schedules. Key elements of interest for future work at this point appear to be in four areas. All apply to enhancing the methodology for predicting fate and transport of contaminants in landfill situations, including: 1) incorporating a methodology for predicting biodegradation of contaminants, 2) addressing speciation reactions of speciatable organic constituents, 3) developing SPARC-based predictors for the necessary modeling parameters, and 4) developing approaches to account for leachate impacts on vadose and saturated zone chemical speciation and transport environments.

Anticipated Major Products
- Revised MINTEQA2 Model with Updated Thermodynamic and Sorption Databases for HWIR (97)
- Characterization of Subsurface Redox Environments for HWIR (97)
- Microbial Community Dynamics of PCB Dechlorination in Sediments (External Grant) (99)
- Rates of Arsenic Oxidation-Reduction Reactions in Contaminated Soils: Effects on Arsenic Fate and Mobility (External Grant) (99)
- Bioavailability of Aromatic Hydrocarbons in Saturated Porous Media: The Effects of Chemical Aging and Mass Transfer (External Grant) (99)

Control Research Activities

Waste Management
Uncertainties still exist regarding the most cost-effective treatment of some hazardous waste streams. There are some hard-to-treat waste streams (e.g., containing mercury) for which it is not possible using current treatment technologies to always obtain desired cleanup levels. In addition, there have been advances in existing, low-cost treatment technologies which make them more broadly applicable to hazardous waste stream remediation.

Current Research Activities
There is currently not a research program in this area.

Future Research Activities
In FY99, research would be initiated in two areas. Laboratory studies would be conducted of immobilization mechanisms for both organic and inorganic contaminants using solidification/stabilization (S/S) in order to determine the effectiveness of S/S to meeting land disposal restriction (LDR) limits for selected wastes. Particular emphasis would be placed on wastes containing organic contaminants for which LDR limits are written on a total concentration basis. Also, pilot-scale evaluations would be conducted on innovative processes claimed to treat mercury (or having potential to do so), including the examination of the form and fate of the metal, to determine the effectiveness of these innovative processes.

Anticipated Major Products
- Evaluation of the Applicability of Solidification/Stabilization Techniques to Organic Constituents in Hazardous Waste Streams (01)
- Report on Treatment of Mercury Contaminated Hazardous Waste Streams (02)

Monitoring Research Activities

Waste Characterization and Sampling

Current Research Activities
This activity provides the new generation of analytical technology need to more accurately characterize complex hazardous waste for the purpose of listing or delisting via methods for inclusion in OSWER's analytical methods manual (SW-846).

This research activity also includes the development a scientific research plan to address issues arising from the initial review of HWIR. This plan is being developed and implemented cooperatively by the ORD and OSW, Office of Enforcement, and NEIC. The purpose of the Multipathway Exposure and Risk Analysis (MERA) Science Plan is to provide direction for establishing an R&D program to address scientific issues and both internal and external comments on a multipathway risk analyses and ground water model developed by EPA. The preliminary models were used to support the proposed Hazardous Waste Identification Rule for as generated wastes, and are being further developed for application to a wide range of EPA programs and regulatory activities. Specific technical issues include model validation, propagation of uncertainties through the models, and how (or whether) uncertainties can be adequately controlled through effective sampling. After completion of the plan, it is anticipated that research activities will focus on representative sampling, cost-effective waste characterization, and the uncertainty of data used as input to models.

Future Research Activities
The ORD/OSW multimedia science plan outlines the approach that will be taken to emphasize the importance of developing guidance for the sampling and analysis of heterogeneous materials and comparing the results to exit levels derived from multipathway, multimedia exposure models. A flowchart will be developed for the recommended sampling and analytical processes and electronic guidance will be developed in later years to allow the regulated community and regulators to use standard approaches to deal with a variety of hazardous materials in a variety of situations.

Anticipated Major Products
For analytical methods products see the previous discussion on field and screening analytical methods in the appendices on ground water and soils.

- Sampling/Monitoring Guidance for Compliance with HWIR Exit Levels (FY2000+)

Summary Tables

The active waste management facilities (AWMF) research plan summary sheet (Table F-1) lists the major products that ORD anticipates it will generate as a result of each AWMF research activity. The table shows the fiscal year (FY) in which the product is projected to be generated, and indicates whether the work is currently funded. or unfunded. A plus mark ("+") means that the product would be funded under the current allocation of ORD research funds. A minus mark ("-") indicates that funding is not currently allocated to this product. A product is considered "currently funded" if there would be adequate funds to develop and complete it under the proposed FY98 President's Budget and FY99 and FY00 budgets that are the same as the proposed FY98 President's Budget.

Table F-1. Waste Research Plan Summary Sheet - Active Waste Management Facilities
("+" = planned, funded product; "-" = anticipated, unfunded product)

RISK PARADIGM	RESEARCH ACTIVITIES/PRODUCTS	SCHEDULE			
		FY97	FY98	FY99	FY00
Hazard Assessment	Develop Provisional Toxicity Values for Contaminants	.....			
	- 25 IRIS Endorsed Consensus Toxicity Values			-	
	- 50 Provisional Toxicity Values		-		
Exposure Assessment	Multimedia, Multipathway Exposure Modeling	.....			
	- User's Manual for Windows-based SPARC Properties Calculator	+			
	- Incorporate SPARC-based, Automated Fate Parameterization Techniques into the Ground Water Modeling System	+			
	- Rewrite of the Multipathway Exposure and Risk Analysis Science Plan		+		
	- Beta Test Version of Multimedia Framework Linking the Screening Models MEPAS, MMSOILS, and RESRAD Together		+		
	- Experimental Validation and Reliability of Multimedia Risk Assessment Models (External Grant)			+	

RISK PARADIGM	RESEARCH ACTIVITIES/PRODUCTS	SCHEDULE			
		FY97	FY98	FY99	FY00
	Environmental Fate and Transport; Physical Estimation	.....			
	- Revised MINTEQA2 Model with Updated Thermodynamic and Sorption Databases for HWIR	+			
	- Characterization of Subsurface Redox Environments for HWIR	+			
	- Rates of Arsenic Oxidation-Reduction Reactions in Contaminated Soil: Effects on Arsenic Fate and Mobility (External Grant)			+	
	- Bioavailability of Aromatic Hydrocarbons in Saturated Porous Media: The Effects of Chemical Aging and Mass Transfer (External Grant)			+	
Risk Characterization	None				
Control	Waste Management				
	- Evaluation of the Applicability of Solidification/Stabilization Techniques to Organic Constituents in Hazardous Waste Streams (01)			.....	
	- Report on Treatment of Mercury Contaminated Hazardous Waste Streams (02)				
Remediation	None				
Monitoring	Waste Characterization and Sampling	.....			
	- Sampling / Monitoring Guidance with HWIR Exit Levels				+

Appendix G
Preliminary Research Plan
Emissions from Waste Combustion Facilities

Contents

Preliminary Research Plan
Emissions from Waste Combustion Facilities

Introduction

As discussed in Chapter 2, a preliminary research plan was developed for each research topic area. The Preliminary Research Plan for Waste Combustion Facilities describes each of the research activities which ORD would conduct from FY97 to FY00 in order to address the most important research needs for waste combustion emissions. Major products are identified for each research activity. A summary table (Table G-1) at the end of the appendix lists these products and indicates the fiscal year in which each will be produced.

Proposed Research Activities

Hazard Assessment Research Activities

Movement of Bioaccumulative Chemicals in Food Webs
Current Research Activities
Currently there is no research being conducted in this area under the direction of this research plan.

Future Research Activities
During the risk ranking exercise, the Waste RCT identified this research area as one that should be considered for future funding. The purpose of this research would be to learn more about possible ecological risks from emissions from waste combustion facilities by studying their transfer and uptake through terrestrial and aquatic food webs. Research would include the identification of indicator species, species-specific exposure rates, and estimates of the bioavailability of contaminants. It would be specifically targeted towards aspects of the issues that are unique to waste combustion sources. Much of the research would consist of obtaining field measurements from different environmental compartments in the food web surrounding waste combustion facilities.

Anticipated Major Products
None are currently planned due to a lack of funding. However, if funds were to become available, the following products might be available:

- Report describing the range of bioavailability for contaminants emitted from waste combustion facilities. (98)
- Report ranking the relative risk of multiple exposure pathways and waste combustion contaminants. (99)

Dose-Response Assessments of Key Contaminants

Current Research Activities

There is currently no research underway in this area under the auspices of the Waste Research Coordination Team.

Future Research Activities

The purpose of this research area would be to develop updated dose-response risk assessments for contaminants of that present the greatest risk from combustion facilities. As more scientific data becomes available in the form of animal toxicological studies, human epidemiological studies, and mechanistic toxicodynamic models, current toxicity values (e.g., Reference Doses, Reference Concentrations, and Cancer Slope Factors) will need to be updated to apply the state-of-the-science and provide a more accurate estimate of risks. Currently, the "risk drivers" are mercury, dioxin, furans, cadmium, and lead. It is likely that one or more of these contaminants may need to be re-evaluated in the future. In addition to updating toxicity values for the above described contaminants, research in this area would also focus on describing dose-response relationships for products of incomplete combustion (PICs).

Anticipated Major Products

- Updated assessment documents and toxicity values (e.g., reference doses, reference concentrations, and cancer slope factors) describing the dose-response relationships of emission contaminants.

Exposure Assessment Research Activities

Indirect Exposure Characterization/Modeling

Current Research Activities

Currently there is no research being conducted in this area under the direction of this research plan

Future Research Activities

This is proposed as a new initiative area for the ORD for FY99. Indirect exposure models related to waste combustion sources will be enhance. Currently models lack the robustness and resolution to provide the fate and transport data needed for accurate exposure and risk assessments. Potential avenues of research include: improved/validated complex terrain models for combustion sources, vapor-particle partitioning of semi-volatile organics (chlorinated dioxins and PAHs) under ambient conditions, air deposition of semi-volatile organics (chlorinated dioxins, PCBs, higher MW chlorinated benzenes/phenols, PAHs, and high MW phthalates), vapor transport to surfaces - wet and dry deposition, surface vapor uptake in plants and animals, mathematical models, parameter characterization, and validation of models for dry gas

deposition and air dispersion, methods for particle size distribution for input to air dispersion models, etc.

Anticipated Major Products

- Improved Understanding of the Fate and Transport of Combustion Emissions (FY2000+)
- Improved Indirect Exposure Models (FY2000+)
- Improved Complex Terrain Models for Combustion Sources (FY2000+)

Indirect Pathway Risk Assessment Methods

Current Research Activities

Indirect Pathway Risk Assessment Methods are a set of procedures that estimate exposures from combustion facilities via indirect (non-inhalation) exposure pathways. These procedures, known as the indirect exposure methodology (IEM), are a multimedia and multi-pathway model which was developed to evaluate the risks from pollutants being emitted from stationary combustion sources. The methodology was developed to provide a set of procedures for the estimation of exposures resulting from emitted pollutants that have been transferred from the atmosphere to environmental media and biota. In addition, indirect exposures may result from uptake and transfer of an atmospheric pollutant through the terrestrial or aquatic food.

Future Research Activities

Assuming funding becomes available, future activities would include refining and validating the algorithm, developing guidance manuals on how to properly select model input parameters, and developing an expert system software package.

Anticipated Major Products

- Draft report describing the Indirect Exposure Methodology. (97)

If funding becomes available, then these additional products will be developed:

- Guidance manuals on selecting model input parameters. (98)
- Expert system software package. (99)

Control Research Activities

Emissions Prevention and Control

Revised regulations are being developed for combustion systems that burn hazardous wastes. These regulations are being developed under the joint authority of the Clean Air Act (CAA) and RCRA. The 1990 CAA Amendments are being used to establish technology based emission limits that are reflective of the application of maximum achievable control technology (MACT) for the control of hazardous air pollutants (HAPs). Revised trial burn guidance requirements and risk assessment requirements

are being developed under RCRA. There are a number of key issues associated with OSW's regulatory strategy: the identification of emission monitors and process parameters for control of HAP pollutants; and the identification of trial burn and risk assessment requirements that insure that the technology based MACT standards are adequately protective of human health and the environment.

The primary goal of this research activity is to conduct research that will lead to a scientific understanding of the factors that control formation and emission of air pollution emissions from combustion sources. These factors include the effects of waste and fuel characteristics, fuel and waste dependent combustion conditions, flue gas cleaning technologies, and the monitoring and process control conditions in managing the formation and emission of air pollutants.

This research activity is part of a broader combustion research program (CRP) that also deals with other selected high temperature thermal treatment processes (pyrolysis systems, plasma are systems, etc.). This program addresses pollutant formation, pollutant control, and emission characterization for all types of stationary high temperature thermal treatment sources. The CRP addresses technical issues of importance to the Agency under RCRA, the CAA and the toxic substance control act (TOSCA). Whenever possible the CRP is structured to meet common research needs of more than one Program Office and the Regional Offices. Many projects are jointly supported.

Current Research Activities

The air toxics emissions controls program is divided into two areas: organics and metals. Organics research is focusing on the characterization of PIC emissions from halogenated wastes and evaluation of surrogate pollutant and process measurement parameters. Dioxin carbon source and formation rate studies are also being conducted. Metals research focusses on projects to: (1) characterize toxic metal transformations in combustion environments and resulting aerosol particle size distribution (PSD), aerosol morphology, and metal speciation; (2) evaluate high temperature sorbents for control of toxic metals by modification of the particle size distribution (PSD); and, (3) evaluate low temperature sorbents for post-combustion control of mercury.

FY97 organics research will focus on the continuation of the PIC characterization studies in the rotary kin simulator, and dioxin formation/control studies in other hazardous waste combustors. PIC research in the rotary kiln will include experiment with surrogate hazardous waste feed mixtures. We will identify major halogenated and non-halogenated PICs. The objectives of dioxin formation research will be to (1) identify the prime carbon sources in PCDD/F synthesis, and (2) measure and compare

global reaction rates for homogenous, in-flight condensation, and de novo type reactions.

FY97 Metals research will use modeling and experiments to investigate Hg speciation as function of flue gas composition (Cl2 and SO2), combustion environment (staging) and temperature. These high temperature experiments will also examine the use of sorbents to capture Hg through chemisorption and by molten mineral eutectics. In conjunction with these high temperature studies, low temperature research will continue examining the fundamentals of mercury adsorption on sorbents in experiments designed to evaluate species dependent adsorption/desorption reactions with the goal of determining kinetic parameters need to model mercury capture by selected sorbents.

Future Research Activities
ORD is writing a strategic plan for its combustion source emissions characterization and control research program and this plan is scheduled to be finalized by September 1997. This plan, which is being developed with input from OSW and OAQPS, will define and prioritize mid to long term research on combustion sources, including incinerators. These research activities will be incorporated into later versions of this Waste Research Plan.

Anticipated Major Products
- Complete evaluation of CEM for continuous monitoring of 20 critical volatile organics compounds (VOCs) (98).
- Complete research on bromine/chlorine interactions (98).
- Complete first phase of research on mercury speciation and sorbent interaction. (98).
- Complete initial PCDD/PCDF formation models with estimates of kinetic rates for condensation (gas phase precursor) and de Novo synthesis reactions (98).

Monitoring Research Activities

Continuous Emissions Monitoring (CEMs)
Current Research Activities
This is a proposed new research activity for FY99. See below for a description of future research.

Future Research Activities
Acceptance of incineration as a viable treatment option for hazardous waste is significantly hindered by our inability to assure on a continuous basis we know the performance of the treatment on the basis of emissions. Efficient, reliable, cost-effective continuous emission monitors (CEMs) are needed. Emphasis will be on toxic metals, dioxins, furans and other semi-volatile organics. Simple, inexpensive methods

are needed for monitoring the thousands of small incinerator (e.g., medical waste incinerators) around the country.

Similarly, improved speciation methods for distinguishing among and measuring the products of incomplete combustion (PICs) are also needed to fully characterize primary and secondary PIC formation from waste combustion.

Anticipated Major Products

- Improved CEMs for Large and Small Combustion Sources (FY2000+)
- Improved Analytical Methods for Detection of PICs from Primary and Secondary Formation (FY2000+)

Summary Tables

The waste combustion facilities research plan summary sheet (Table G-1) lists the major products that ORD anticipates it will generate as a result of each waste combustion facilities research activity. The table shows the fiscal year (FY) in which the product is projected to be generated, and indicates whether the work is currently funded or unfunded. A plus mark ("+") means that the product would be funded under the current allocation of ORD research funds. A minus mark ("-") indicates that funding is not currently allocated to this product. A product is considered "currently funded" if there would be adequate funds to develop and complete it under the proposed FY98 President's Budget and FY99 and FY00 budgets that are the same as the proposed FY98 President's Budget.

Table G-1. Waste Research Plan Summary Sheet - Combustion Facilities
("+" = planned, funded product; "-" = anticipated, unfunded product)

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Hazard Assessment	Movement of Bioaccumulative Chemicals in Food Webs			.....	
	- Report Describing the Range of Bioavailability for Contaminants Emitted from Waste Combustion Facilities		-		
	- Report Ranking the Relative Risks of Multiple Exposure Pathways and Waste Combustion Contaminants			-	
	Dose Response of Key Contaminants			.....	
	- Updated Assessment Documents and Toxicity Values Describing the Dose-Response Relationships of Emission Contaminants				
Exposure Assessment	Indirect Exposure Characterization/Modeling			.....	
	- Improved Understanding of the Fate and Transport of Combustion Emissions			-	
	- Improved Indirect Exposure Models			-	
	- Improved Complex Terrain Models for Combustion Sources			-	
	Indirect Pathway Risk Assessment Methods			.....	
	- Report Describing the Indirect Exposure Methodology (IED)	+			
	- Guidance Manuals on Selecting Model Input Parameters		-		
	- Expert System Software Package			-	

RISK PARADIGM	RESEARCH ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Control	Emissions Prevention and Control				
	- Complete evaluation of CEM for continuous monitoring of 20 critical volatile organics compounds (VOCs) (98).		+		
	- Complete research on bromine/chlorine interactions (98).		+		
	- Complete first phase of research on mercury interaction (98).		+		
	- Complete initial PCDD/PCDF formation models with estimates of kinetic rates for condensation (gas phase precursor) and de Novo synthesis reactions (98).		+		
	None				
Remediation					
Monitoring	Continuous Emissions Monitoring (CEMs) Methods			.....	
	- Improved CEMs for Large and Small Combustion Sources			-	
	- Improved Analytical Methods for Detection PICs from Primary and Secondary Formation			-	

Appendix H
Preliminary Research Plan
Technical Support

Contents

Preliminary Research Plan
Technical Support

Introduction

This section describes site-specific assistance technical support activities where formal support centers/programs have been established in ORD. It also describes technical support in the form of program office and technology transfer activities where major, formal programs exist in ORD.

Proposed Support Activities

Exposure Assessment Technical Support

Center for Exposure Assessment Modeling (CEAM)
The Center for Exposure Assessment Modeling goal is to meet the scientific and technical exposure assessment needs of the EPA and the state environmental and resource management agencies. To support the agency and professional community in environmental risk-based decision making, CEAM works to expand the applications expertise for quantitatively assessing pollutant exposure as part of human and ecological risk assessments.

Current Activities
CEAM prepares, distributes, maintains, and supports software products that can be used in environmental modeling and assessment. In addition to software distribution, CEAM reviews and evaluates potential and existing software products; maintains and tests FORTRAN and other master language source code and command files; provides users support that includes review, evaluation and possible correction of run time errors or other problems encountered when using CEAM software.

Future Activities
It is anticipated that additional technical support for the new generation of multimedia, multipathway exposure models will be requires, especially in support of the OSW regulatory strategies identified in the Hazardous Waste Identification Rule and as the states assume more direct responsibility for Superfund.

Anticipated Major Products
- Benchmarking Multimedia Models
- Model Software Distribution and Technical Assistance

Risk Assessment Technical Support

Superfund Health Risk Technical Support Center

Current Activities

The Superfund Health Risk Support Center, managed out of NCEA's Cincinnati Division provides risk assessment support primarily to EPA's regions and to other risk assessors conducting risk assessments at Superfund waste sites. When requested, currently available risk assessment toxicological information within the center can also be provided to risk assessors associated with other federal and state agencies. Additionally, the center updates all previously assessed contaminants on a two year cycle and when completed, this information is transmitted to the Superfund Headquarters office (OERR) and the regional superfund risk assessors. NCEA and OERR have agreed to peer review these updated risk assessments which are then incorporated in the Health Effects Assessment Summary Tables (HEAST). These peer-reviewed assessments provide much more scientifically credible toxicity values than previously developed provisional assessments which receive only limited internal scientific review. Peer review is a major planned activity and the center eventually plans to require all major products to be peer reviewed before they are available to Superfund risk assessors. The technical support center also conducts reviews of regional risk assessments and provides expert testimony when needed.

Future Activities

Future activities are expected to remain similar to current activities, depending of course, on the availability of funding.

Anticipated Major Products

- Revised peer-reviewed risk assessments on TNB (peer review process complete) and Barium (to be peer reviewed in June/July). Draft report In FY'97

RCRA Combustion Risk Technical Support Center

Current Activities

The Office of Solid Waste and the Office of Research and Development have established a pilot Resource Conservation and Recovery Act (RCRA) Combustion Technical Support Center to provide technical assistance to EPA personnel conducting or evaluating combustion risk assessments. The pilot center is expected to begin operation Spring 1997 and its continued operation will be evaluated after 1 year.

The goal of the Combustion technical support center is to provide state-of-the-science site and chemical-specific support for RCRA combustion sites. Guidance is expected to be provided in the areas of emissions characterization, short and long-term hazard assessments, chemical-specific fate and transport modeling, and exposure scenario

modeling. The center will provide services directly to the U.S.EPA Regions on a rapid response basis.

Future Activities
Since the center will begin operation as a pilot project for a period of one year, future activities are uncertain at this time.

Anticipated Major Products
- Technical assistance to Regional risk assessors on RCRA combustion issues.
- A compendium summarizing requests for assistance and responses provided to regional risk assessors. Requests and responses will be categorized by scientific issue, component of the risk assessment paradigm and will then be used to try to identify data gaps and future research needs.

Ecological Risk Assessment Technical Support Center
Current Activities
Due to resource constraints (e.g., lack of staff, and dollars), there is currently no on-going activity in this area.

Future Activities
The Superfund and regional offices have identified establishment of an Ecological Risk Technical Support Center as a priority need. Such a center is currently unfunded due to a lack of resources (both dollars and staff/personnel). If the center were established, its mission would be to provide support primarily to EPA's regions and to other risk assessors conducting ecological risk assessments of Superfund waste sites. Assistance would be provided on a full range of ecorisk issues including: problem formulation, hazard identification, stressor-response, exposure assessment, and risk characterization. A data base of cleanup standards and criteria could also be established to assist risk managers for sites driven by ecorisk issues. The center would serve as a “clearinghouse” for ecological risk data needs for Superfund waste sites. Like the existing Health Risk Technical Support Center, peer review would be a major planned activity. Finally, the ecological risk technical support center could also conduct reviews of regional risk assessments and provide expert testimony when needed.

Anticipated Major Products
- Various items depending on the nature of the request but expected to include: short consultations on specific questions, peer reviews of ecological risk assessments, literature searches of ecotoxicity data bases, and assistance with the development of ecorisk cleanup levels.

Remediation Technical Support

The remediation technical support program is designed to ensure that EPA's regional staff,program offices and others have access to current and accurate information on all phases of site cleanup. Technical support translates science and engineering research into practical field applications by direct assistance on a site-specific and multi-site basis, publications, and workshops. On-site technical support also provides a feedback loop on science and technology performance to ORD researcher. As such, technical support is an important step in answering each of the science questions covered in this research plan.

The goals of the program are to make site cleanup better, faster, and cheaper *via* a program of three components: 1) site-specific assistance, 2) program office support, and 3) information transfer (i.e., technology transfer).

Remediation Site-Specific Technical Support
Site-specific technical support is provided on a wide variety of technical problems where the Regions require expert opinion on state-of-the-science issue. Support ranges from reviewing technical documents prepared by site owners or Regional Office contractors, to visiting sites and making technical recommendations on the selection and implementation of cleanup options, to conducting site-specific lab and field investigations.

Remediation of uncontrolled or poorly managed waste disposal sites is a major focus of the Agency and represents a substantial expenditure of tax funds and industry resources. In the Superfund program, EPA annually expends more than $800M in site cleanup. Criticism of the remediation program under both Superfund and RCRA focused on slowness, high cost, and apparent lack of scientific grounding. The purpose of the site-specific technical support program is to apply ORD's science and engineering knowledge directly to in-progress remediation activities. The intent is to provide state-of-the-science information to remediation managers and practitioners that will allow them to make timely, cost-effective decisions. The close working relationship between researchers and practitioners also fosters rapid translation of emerging technologies to field application.

The types of remediation technical support will shift over time principally due to the fact that more and more sites will be in the remedy design and implementation stage, rather than the technology selection stage. Consequently, there will be a greater demand for in-depth technical evaluation, as opposed to broad technology evaluation support.

Current Activities

Elements of the site-specific remediation assistance program are:

- Engineering &Treatment and Ground Water Fate & Transport Technical Support Centers. These centers, part of a cooperative project among OSWER, ORD and EPA Regions, provide responses to regional requests for assistance on contamination problems and potential remediation techniques. Focus areas include wastes, soils, the vadose zone, and ground water, covering all the issues related to contaminant transport, interception, and management or destruction. The support centers serve both the Superfund and RCRA programs. Assistance actions are most often include reviews of work plans, proposals, test results, and designs.
- Superfund Technical Assistance Response Team (START). START provides ongoing support for cleanup of particularly complex or contentious Superfund sites. The START leader and regional project manager assemble a team to address specific problems or reach selected decision points, often via technical discussions with potentially responsible parties and the affected community. Assistance actions generally include site visits and meetings, and often include conduct of laboratory or field studies to resolve technical problems.
- Treatability Study Assistance Program (TSAP). TSAP is a full-service laboratory program aimed at providing EPA's project manager with the ability to conduct site-specific treatability tests or to provide oversight verification of responsible party testing. TSAP focuses on newer or innovative applications of technology, using a research focus not readily found in the contract lab setting.

Future Activities

In FY98 and beyond, ORD expects demand for site-specific assistance to continue at a slow annual growth or remain steady at current levels. While the level of expertise among remediation managers and practitioners continues to grow, new science and technology developments occur faster than conventional technology transfer mechanisms. Demand for site-specific technical support may increase as a result of changes made in Superfund reauthorization legislation or delegation of implementation responsibilities to the states. It is also anticipated that adjustments will be made to the program in response to available funds and to changing client priorities.

Anticipated Major Products

The level of site-specific remediation technical support activities is heavily dependent upon the level of funding, which is very uncertain at this time. The number of staff committed to the program is expected to remain constant as long as the funding remains constant. Given the uncertain resources, ORD will place its emphasis on maintaining the technical support centers, which provide respond to about 300 "short term" site-specific assistance requests annually. The START program will be "downsized" and support about 10 sites per year. The Treatability Study Assistance

Program will be phased out in FY97 due to decreasing need because the majority of Superfund sites are now in the post-record-of-decision (ROD) phase.

- On-site technical assistance to Regional Superfund staff on Superfund remediation technology issues.

Remediation Program Office Support

OSWER develops remediation regulations, policies and guidelines under CERCLA and RCRA, and sometimes calls upon ORD to assist with development of technical aspects of these products. ORD's depth of expertise in remediation research and site-specific technical support allows the Office to effectively provide such assistance. ORD reviews the scientific and technical foundation of proposed OSWER rules, policies, and decisions, and participates in workgroups for their development. In selected cases ORD provides substantive scientific/technical foundation to support OSWER rules, policies, and decisions, including conducting research or analyzing research results. ORD also assists in implementing, refining, or evaluating program rules, policies, and decisions. For example, ORD has assisted in the development of guidance on the applicability of incineration and solidification/stabilization; presumptive remedies; soil screening levels; and technical impracticability. The objective of this type of technical support is to provide technically sound information to OSWER to support regulations and policies.

Current Activities

ORD is providing remediation support to OSWER in the following areas: Brownfields, presumptive remedies and natural attenuation.

Future Activities

ORD will continue to provide remediation support to OSWER on areas that are high priority to OSWER and in which ORD has the technical expertise and on going research activities.

Anticipated Major Products

The major formal products of this support are information transfer products such as documents, seminars and workshops. In addition, ORD provides assistance through internal technical memoranda and discussions. Products related to natural attenuation may be found in the discussions of Natural Attenuation of Ground Water and the Biotreatment of Soils research activity descriptions in Appendices D and E, respectively. Products related to Brownfields and Presumptive Remedies are listed in the subsection on Remediation Technology Transfer, immediately below.

Remediation Technology Transfer

Technology transfer is an important component to ORD's waste research program, serving as a means to efficiently disseminate information to a wide range of stakeholders who benefit from having state-of-the-art solutions to remediation problems. ORD's remediation technology transfer programs have put particular emphasis on informing Regional staff (e.g., Remedial Project Managers, RCRA permitters) and their contractors about remediation options, and have supported OSWER in the dissemination of technical information on new remediation guidance (e.g., presumptive remedies, technical impracticability).

One of the benefits of a strong remediation technology transfer component to ORD's research program has been to supplement ORD's site-specific technical assistance activities (described elsewhere), thereby, reducing the number of requests for assistance on "routine" site-specific problems.

Technology transfer is carried out through a number of means, including the production of documents, maintenance of electronic databases, delivery of workshops and transmittal of information through the Internet.

The objective of the program is to select the highest priority remediation issues that can benefit from technology transfer and to deliver information as effectively as possible to those stakeholders who most need it.

Current Activities

In FY97, the program is focusing on remediation problems that are quite complex and/or of high priority to the Agency. Examples are: Brownfields sites, wood preserver sites and contaminated sediments. Databases such as the Alternative Treatment Technology Information Center (ATTIC) will be maintained at their current operating capabilities.

Future Activities

Future remediation technology transfer activities will be determined with input from EPA scientists and engineers, OSWER and the Regions, and other stakeholders. The selection of specific topics is dependent on the priority to stakeholders, the status of research in specified areas, and the need for this information to be disseminated quickly. Thus, topics will reflect changes in program direction. For example, as information on *in situ* technologies, less costly technologies and containment becomes available, technology transfer will focus on these topics.

A trend in the selection of future remediation technology transfer activities will be to identify the needs of a broader clientele such as communities/local decision makers, and to develop technology transfer products that will meet their needs as well as the needs of EPA's traditional technical user clientele. For example, it is expected that

there will be a greater focus on "fact sheets" that address issues of importance to the general environmental community.

Specific topics that are under consideration for information transfer include descriptions of remediation options for specific contaminants (e.g., Pb, Cr (VI)) and media (e.g, contaminated sediments), as well as discussion of solutions to air pathways exposure issues.

The means of transferring information will also change in the next several years as the program seeks the optimum media for outreach. For example, greater use of electronic forms of technology transfer will be required due to the need to update information more rapidly and cost-effectively than hard copy.

Anticipated Major Products
Technology transfer activities are generally developed on a year-to-year basis in response to pressing stakeholder needs. Therefore, it is difficult to project specific future products. In FY97, technology transfer products will include:

- A guidance document on characterization technologies, remediation technologies and cost estimation techniques to facilitate the Brownfields Initiative (98).
- A document on treatment of contaminated wood-preserver sites and several seminars to present the results of treatability tests for wood- preserver sites (97).
- Compendium of Methods for Measurement of Inorganic Compounds in Ambient Air (98).
- Compendium of Methods for Measurement of Toxic Organic Compounds in Ambient Air (98).

Monitoring Technical Support

Environmental Photographic Interpretation Center (EPIC)
Current Activities
Aerial photo interpretation and remote sensing support is provided through the Environmental Photographic Interpretation Center (EPIC) to the Superfund and RCRA Regional and Program Offices in the form of detailed current and historical waste site characterizations, showing site conditions and activities often as far back as the 1930's. Photo interpretation and remote sensing also provides the Regional and Program Offices with guide maps illustrating areas impacted, and supporting cleanup activities, during emergency spill events or other disasters. This technology also supports EPA enforcement efforts through the use of expert witness testimony and courtroom documentation to describe and illustrate site conditions and activities. From the programs inception to present the EPIC has conducted more than 7,000 assistance

actions in the form of aerial photo and remote sensing data acquisition, image processing, data analysis, map production, and waste disposal site characterization.

Future Activities
EPIC will continue to provide technical assistance and support in the above areas. It is anticipated that the programs and regions will be asking for more products in a digital format and in a GIS context to support their site characterization needs. It is also anticipated the future requests will also include the use of products based on satellite based imagery from multispectral sensors.

Anticipated Major Products
EPIC will continue to provide the following kinds of remote sensing products and assistance:

- *Photo Acquisition* - the searching and acquisition of historical aerial photographs from archives located across the U.S., or the overflight and acquisition of new aerial photographs.
- *Site Analysis* - the analysis of current or historical aerial photographs to characterize the waste disposal activities at active or abandoned sites.
- *Litigation Support* - the provision of courtroom documentation or expert witness testimony in support of EPA litigation.
- *Photogrammetry* - the measurement of features, materials, or excavations (heights, depths, volumes) at waste disposal sites or the production of accurate maps (topographic or thematic) for these sites.
- *Geographic Information Systems* - applying computerized systems for incorporating, integrating, displaying and analyzing spatial data in relation to hazardous waste disposal sites and associated anthropogenic activities and natural resources/features.
- *Emergency Response* - responding to Regional requests for emergency response support usually in response to a spill of hazardous materials on the land or into water bodies. Requires the collection of current aerial photos through overflight of the incident, and the analysis of the areal extent, containment, and cleanup of the spill.

Monitoring and Characterization Technical Support Center (TSC)
Current Activities
Site specific technical support is offered for complex site-specific contaminate characterization projects. From inception FY88-89 through FY96, NERL's Technical Support Center (TSC) have addressed more than 1200 assistance actions in support of more than 410 Superfund sites and RCRA corrective action facilities. The TSC for monitoring and site characterization provides and implements cost and time effective technologies for identifying the levels and geographical extent of contaminants and

determining a contaminates bioavailable species for risk and exposure assessment purposes. Examples of previous projects include:

- On-site characterization of metals, oils, creosotes, tars and phenols utilizing ion mobility spectrometry, field-portable scanning spectrofluorometer and field portable X-Ray fluorescence at wood preservative, coal gasification, mining and smelter sites.
- Bioavailable determination for mercuries, cyanides and lead.
- Data assessments at sites with sediment contamination that have resulted in cost effective remedial decisions.

Future Activities

The TSC will continue to support the program offices and the regions for the foreseeable future. Increased technical support is anticipated in the areas of evaluating (monitoring and site characterization) sites as potential candidates for a natural attenuation remedy selection and in support of States and local communities in characterizing Brownfield sites.

Anticipated Major Products

- Continued site specific technical support in monitoring and site characterization.
- Requested state-of -the-science Issue Papers, e.g.:
  - Lognormal Distribution in Environmental Applications
  - Field Sampling and On-Site Analytical Methods for Explosives in Soil

Active Waste Management Facilities (Including Combustion) Technical Support

Exposure assessment and monitoring technical support are provided through the same programs described earlier in this subsection for contaminated sites. Technical support for combustion control is presently provided on an *ad hoc* basis to OSW and the Regions.

Summary Tables

The technical support research plan summary sheet (Table H-1) lists the major products that ORD anticipates it will generate as a result of each technical support activity. The table shows the fiscal year (FY) in which the product is projected to be generated, and indicates whether the work is currently funded. A plus mark (“+”) means that the product would be funded under the current allocation of ORD research funds. A minus mark (“-”) indicates that funding is not currently allocated to this product. A product is considered “currently funded” if there would be adequate funds to develop and complete it under the proposed FY98 President’s Budget and FY99 and FY00 budgets that are the same as the proposed FY98 President’s Budget.

Table H-1. Waste Research Plan Summary Sheet - Technical Support
("+" = planned, funded product; "-" = anticipated, unfunded product)

RISK PARADIGM	SUPPORT ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
Risk Assessment	Superfund Health Risk Technical Support - Assistance to Regional Risk Assessors on Superfund Human Health Risk Issues - Risk Assessments on TNB and Barium	..... <.....ongoing.....>			
	RCRA Combustion Risk Technical Support - Assistance to Regional Risk Assessors on RCRA Combustion Issues	..... <.....ongoing.....>			
	Ecological Risk Assessment Technical Support Center - Assistance to Regional Risk Assessors on Ecological Risk Issues	..... <.....ongoing.....>			
Exposure Assessment	Center for Exposure Assessment Modeling - Benchmarking Multimedia Models - Model Software Distribution and Technical Assistance	..... + + <.....ongoing.....>			
Remediation	Remediation Site-Specific Technical Support - Assistance to Regional Superfund Staff on Superfund Remediation Technology Issues	..... <.....ongoing.....>			
	Remediation Program Office Support	<.....ongoing.....>			

RISK PARADIGM	SUPPORT ACTIVITIES	SCHEDULE			
		FY97	FY98	FY99	FY00
	Remediation Technology Transfer	.....			
	- Guidance Document on Characterization Technologies, Remediation Technologies and Cost Estimation Techniques to Facilitate the Brownfields Initiative	+			
	- Document on Treatment of Contaminated Wood-preserver Sites and Several Seminars to Present the Results of Treatability Tests for Wood- Preserver Sites	+			
	- Compendium of Methods for Measurement of Inorganic Compounds in Ambient Air	+			
	- Compendium of Methods for Measurement of Toxic Organic Compounds in Ambient Air	+			
Monitoring	Environmental Photographic Interpretation Center (EPIC)	.....			
	- Remote Sensing Technical Support to the Program Offices and Regions	<.....ongoing.....>			
	Monitoring and Characterization Technical Support Center	.....			
	- Continued Site-Specific Technical Support in Monitoring and Site Characterization	<.....ongoing.....>			
	- Issue Paper --- Lognormal Distributions in Environmental Applications	+			
	- Issue Paper --- Field Sampling and On-site Analytical Methods for Explosives in Soil	+			